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The Welding Journal

THE JOURNAL OF THE AMERICAN WELDING SOCIETY PUBLISHED FOR THE ADVANCEMENT OF THE SCIENCE AND ART OF WELDING

VOLUME 16 JUNE 1937 NUMBER 6

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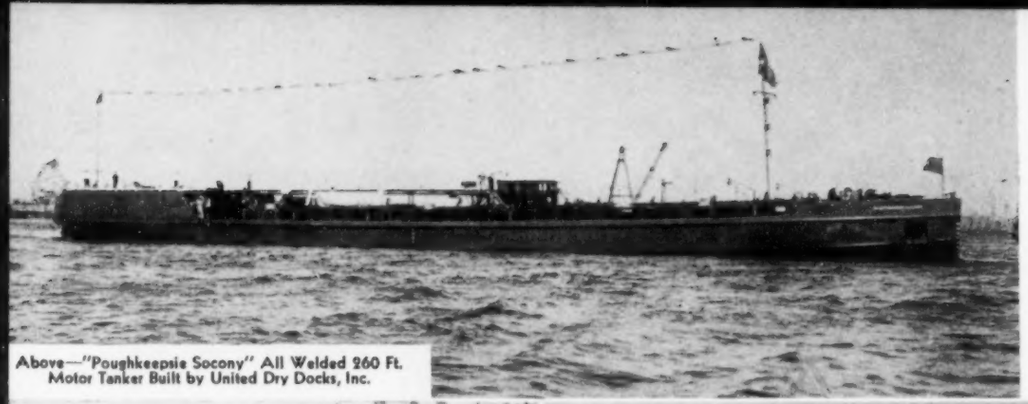
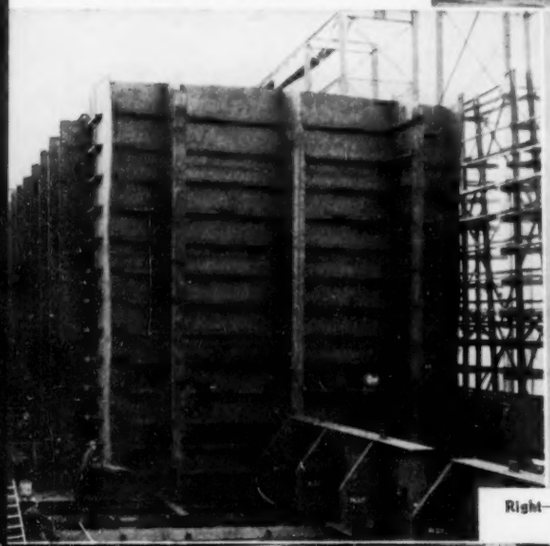
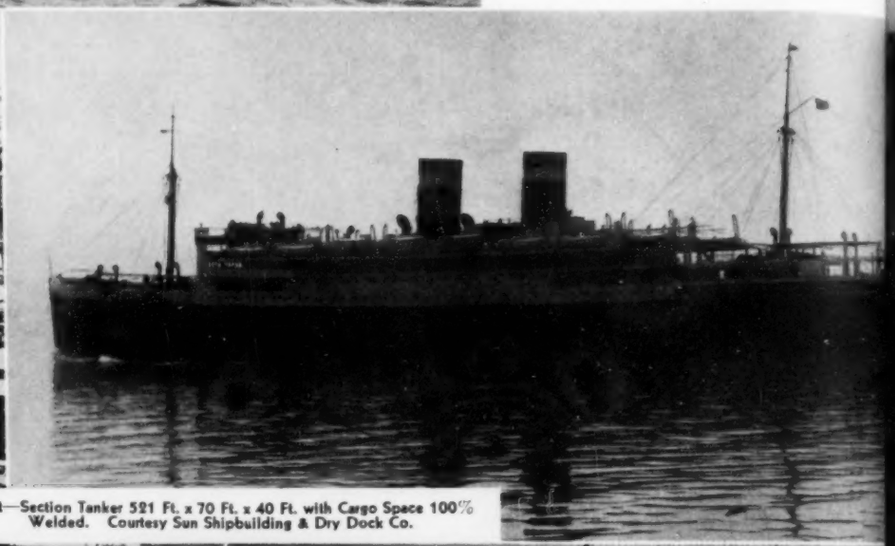
The Success of Wel arges



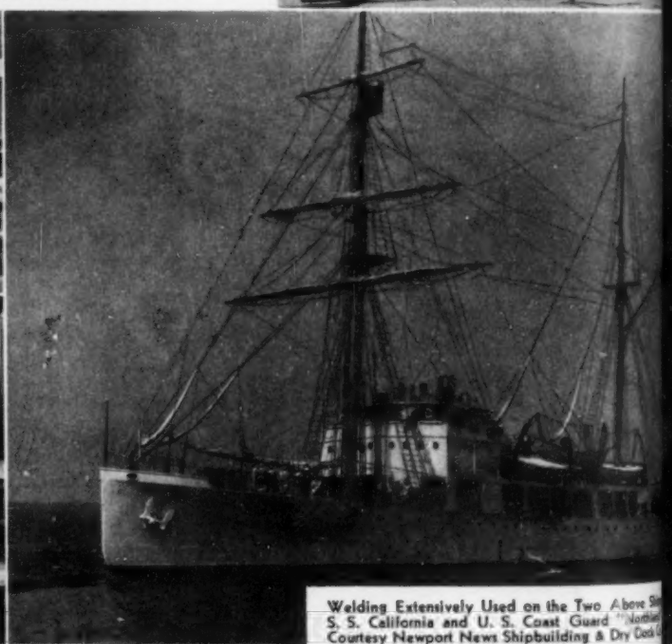
Above—"Poughkeepsie Socony" All Welded 260 Ft. Motor Tanker Built by United Dry Docks, Inc.





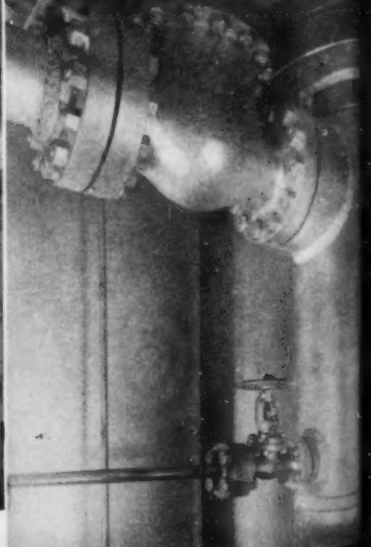
Right—Section Tanker 521 Ft. x 70 Ft. x 40 Ft. with Cargo Space 100% Welded. Courtesy Sun Shipbuilding & Dry Dock Co.

Dolomite—All Welded 217 Ft. Steel Freighter. Courtesy Lincoln Electric Co.



Welding Extensively Used on the Two Above Sh S. S. California and U. S. Coast Guard Mo Courtesy Newport News Shipbuilding & Dry Dock

Above—Detail Interior Welded Coal Barge—Dravo Contracting Co.



Left—Welding Rudder for a New Steamboat—Courtesy U. S. Steel Corp. Above—Interior View All Welded Hospital Ship. Courtesy Lincoln Electric Co. Right—

NG THE SEAS WITH WELDING

g in Construction of Large Size Steel Barges Now General Practice

Wel arges in the Harbor and River Trades Has Led to Their Use in Coastwide Service

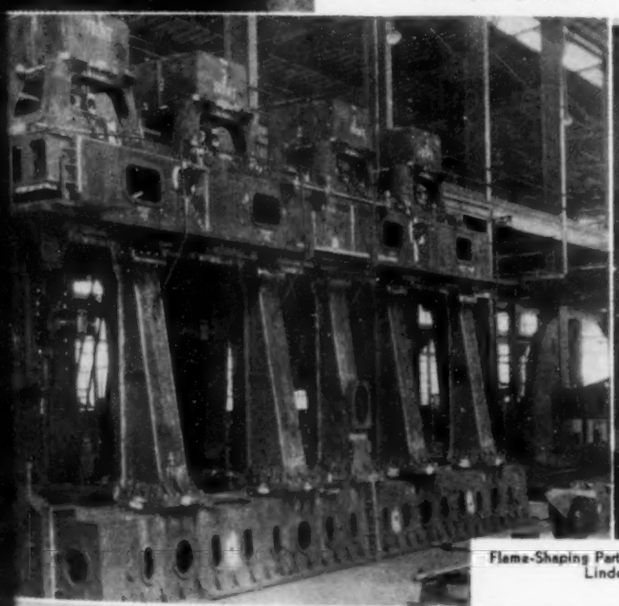
TODAY all welded oil tankers up to 260 ft. in length are operating successfully. Welding has also entered the larger ship field. Many large vessels have welded hold pillars, auxiliary machinery foundations, bulkheads, piping and many other miscellaneous welded details. Welding has resulted in a saving in weight of 10 to 15% of steel used in ship construction. There are under construction in Chester, two 521 tankers which will be almost completely welded.

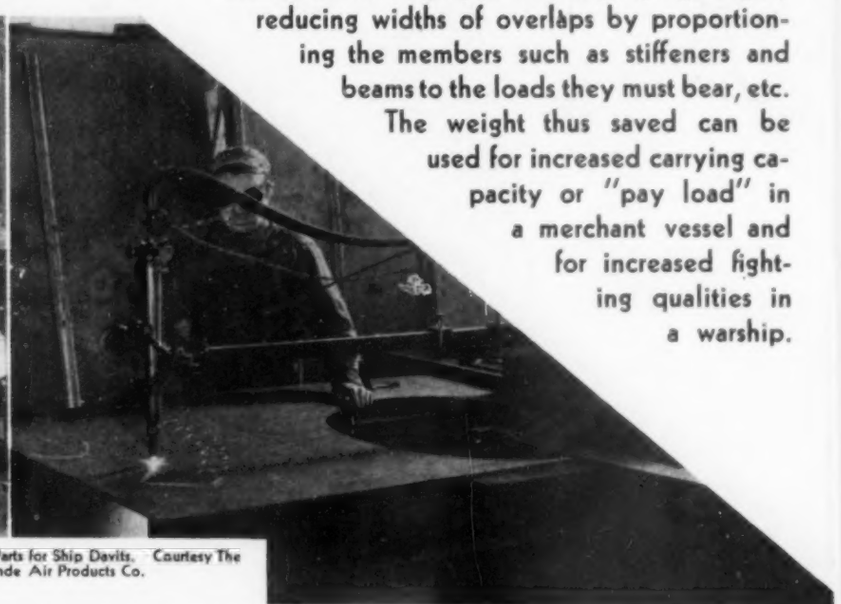
In the construction of piping and pressure vessels for high temperatures and pressures needed on board vessel, welding is destined to displace existing methods of construction.

In naval vessels riveting is still used for connection of ballistic plating, and main strength members, but welding has replaced riveting in most of the other parts of the structure and in practically all fittings.

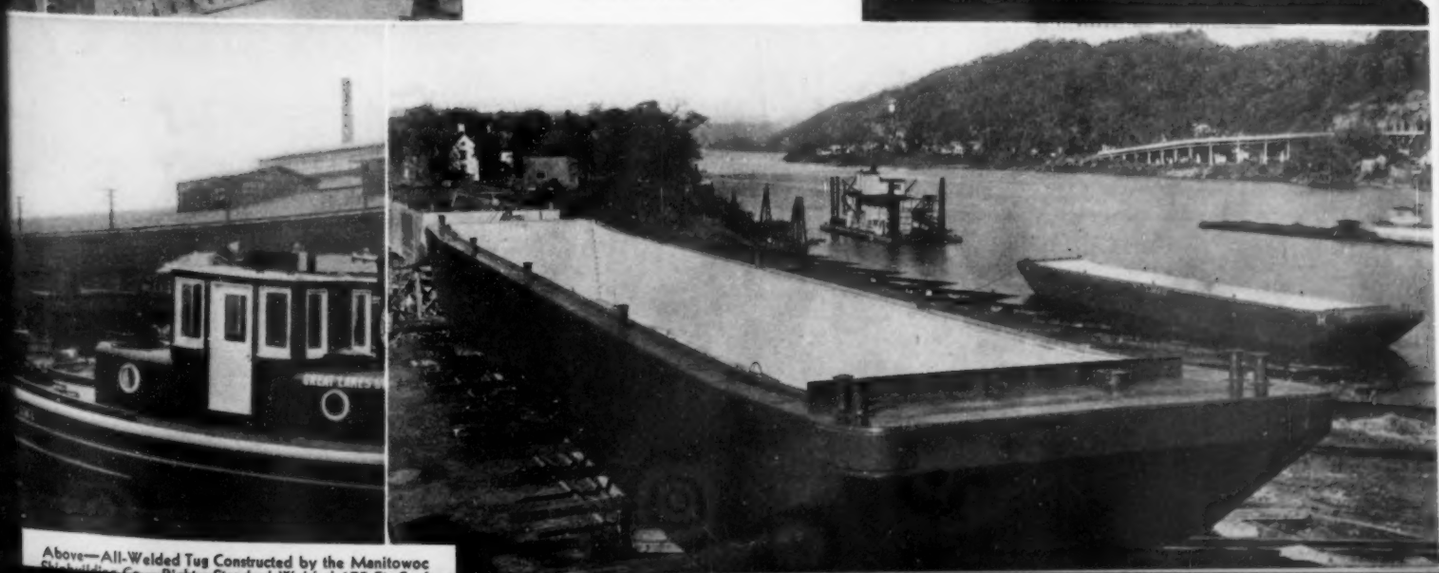
There can be little doubt that a material saving in weight can be effected in designing structures for the use of welding by eliminating faying flanges, reducing widths of overlaps by proportioning the members such as stiffeners and beams to the loads they must bear, etc. The weight thus saved can be used for increased carrying capacity or "pay load" in a merchant vessel and for increased fighting qualities in a warship.

Air Storage Tank for Marine Service. Below—Welded Marine Engine. Courtesy Sun Shipbuilding & Dry Dock Co.





Flame-Shaping Parts for Ship Davits. Courtesy The Linde Air Products Co.

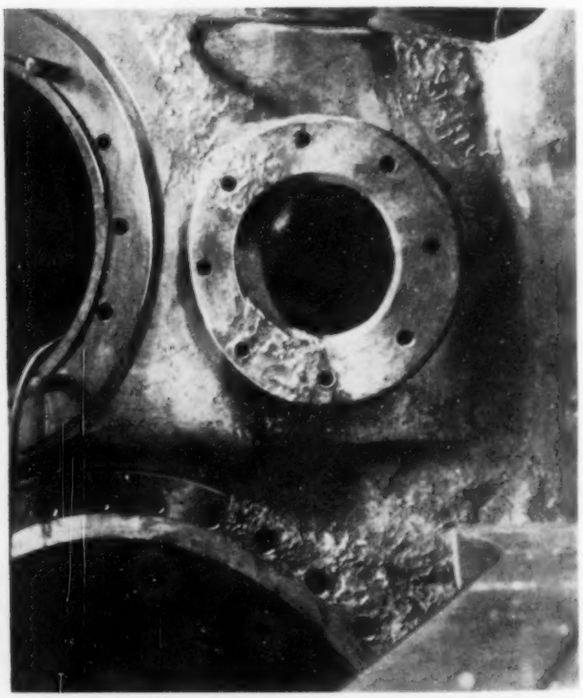


Above—All-Welded Tug Constructed by the Manitowoc

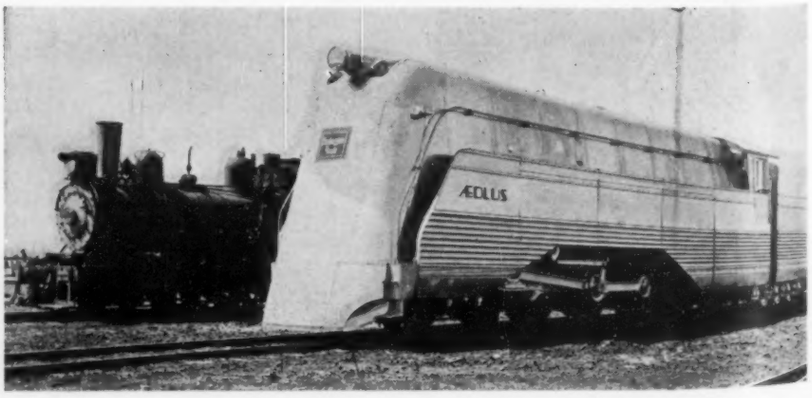
Welding in the Railroads—Continued from the May Issue

Electric Flash Welded Joint. Courtesy Delaware & Hudson Railroad

Upper, Thermit Welded Tracks, Albany, N. Y. Lower, Unloading Long Lengths of Thermit Welded Rails from Flat Cars. Courtesy Delaware & Hudson Railroad



Bronze-Welding in Repair of Locomotive Cylinders. Courtesy American Brass Co.



Welding Assists Engineers in Construction of Wonder Engine, Aeolus of Burlington Railroad. Courtesy *Steel*

Residual Stresses

EDITORIAL NOTE.—*With some hesitation the Editor reproduces below some of the comments received on a short article presented for publication on the above subject. These discussions are necessarily brief and give at times evidence of incomplete understanding of the complicated problems involved. The wisdom of regulatory bodies to proceed cautiously is particularly brought out as is also the need for further research work.*

Locked-Up Stresses

By C. J. HOLSLAG, Electric Arc Cutting & Welding Co.

THERE are no harmful locked-up stresses in mild steel welding. There is entirely too much investigation into this fairyland fallacy because in any one's experience with welding either gas, thermit or arc or rivet or any deformation of metal, there is no such thing as locked-up stresses in mild steel; at least, they do not exist to an extent that will ever become harmful. I sincerely believe that these locked-up stresses are more theoretically damaging than real.

There are locked-up stresses in a tank or boiler plate rolled cold. I never heard of any stress relief being necessary. There must be locked-up stresses in forging, riveting, drawing or in any process in which the metal is deformed but those people claim, and rightly too, that working the metal increases its desirable physical property. Surely, forging is better than casting and a cold-rolled steel plate or drawn wire is an improved form of metal but they must certainly be full of terrible locked-up stresses.

There has never been any failure of an electric welded joint due to the so-called locked-up stresses.

A little simple thinking would show you that there is nothing to fear.

First, the property of most metals and certainly that of steel is increased by continued working hot or cold.

Second, if any one doubts it let them tensile test a piece of steel welded or unwelded beyond the elastic limit to less than the ultimate strength, leaving it in the machine overnight, testing a control piece to complete ultimate strength at the same time. The next day it will be found that this piece has higher ultimate strength than the unstrained and if the third and fourth and fifth piece is left in the machine as many days, it will be found each day increases the strength of the steel.

Third, granted then that stretching steel beyond the elastic limit and not beyond the ultimate strength is not harmful, where is the danger?

If the welding heat stretches the steel beyond the elastic limit, it is improved. If it stretches it up to the elastic limit but not beyond it, you still have approximately 50% safety factor and no structure is designed without a safety factor of three or four or more.

The heating of arc welding performs its own testing because reflection will show that if the stretching is beyond the ultimate strength the weld will break or part from the parent metal if the weld is not good. This self-test is also a comforting thought and it is very real because all the failures of arc welding occur within the first ten or twelve hours and certainly within the twenty-four hours. Once beyond that period there is no record of any failure due to heating strains. Furthermore, an aging occurs in mild steel completely eliminating all stresses.

Due to these facts I think we should lock up the file on alleged harmful stresses even for gas and thermit welding and certainly for electric welding.

Discussions

By C. A. ADAMS, Chairman, Welding Research Committee, Engineering Foundation.

"Except in rare instances, residual stresses in mild steel stuctures are not important or dangerous, but these rare instances do occur, and have occurred. This occurrence, however infrequent, makes regulatory bodies necessarily cautious, particularly when the function of these bodies is primarily safety. Thus, in the absence of more definite and rational knowledge of a quantitative nature, safety bodies must cover this 'no man's land of ignorance.'"

"The general conclusions reached are briefly as follows:

(1) Whenever a weld is made between two plates of mild steel, the contraction of the cooling metal in the region of the weld sets up stresses which exceed the yield point value (which is approximately one-half of the tensile strength), with the resulting plastic stretching or deformation of the material in that region. But this plastic deformation does not reduce the stress below the yield point value; and in the case of a straight joint between two plates, a residual stress exactly equal to the yield point value exists usually along the center line of the weld and in a longitudinal direction—that is, along the line of the weld. Transverse stresses are also present, but they are usually less regular and much dependent upon the technique of welding.

(2) As you move sidewise away from the weld, this longitudinal stress drops off rapidly; and in the case of two flat plates actually reverses and becomes compression stress toward the outer edges. Logically this must be so in order to have static equilibrium.

(3) We do know that most metals under continuous stress tend to flow, or yield, very slowly. This phenomena is commonly called "Creep," but this creep is very small and very slow at stresses below the yield point at ordinary temperatures. Even at these ordinary temperatures there will doubtless be some slight creep in the course of time—but we have as yet no accurate quantitative evidence as to the rate of decay of these stresses, or of the point at which this decay stops. We do know, however, that this decay is slow, and that it varies with different materials. If, however, the welded structure be held for long periods in the region of 900 or 1000° F., there will be a sufficient creep to reduce the stress to probably less than one-half of the cold yield point value. As a matter of fact, if held at 1150 or 1200° F. for an hour or two, the stress would be reduced from the yield point value of about 30,000 lb. per sq. in. in mild steel to about 5000 lb. per sq. in. This is the process which is called "stress-relieving," and the figures which I have given are all results of experiments as well as consistent with our knowledge of properties of the material in question.

Although I have thus far made no mention of peen-

ing, it is a well known fact that this operation is absolutely essential in order to avoid the cracking open of welds made in heavy plates due to the residual stresses. However, it is also well known that peening does not eliminate these stresses, as there is no simple gage to tell us when the peening has been carried just far enough. Moreover, it may be stated without fear of contradiction that even in the best regulated shops where peening is practiced regularly, there will always be regions in which residual stresses are at the yield point.

As I have stated before, these residual stresses are, in most cases, wholly innocent as far as the safety of the structure is concerned. The critical factor is the stress gradient, that is the slope of the stress curve across the welded joint, or the abruptness of the change of stress from one point to another along this transverse line.

All of these considerations point to the importance, from the point of view of both sides of the controversy, of obtaining at the earliest possible moment the necessary rational and quantitative knowledge.

My own efforts in this field are solely aimed at closing this gap of ignorance as far as is possible, since the result of such a closure in whatever degree would undoubtedly mean a corresponding reduction in the safety precautions in fields where they are now required. It would also mean a saving of money on the part of industry as a whole."

By DONALD G. MAXSON, Electric Boat Company.

Mr. Holslags article on the "Bugaboo" of "Locked-Up Stresses" as applied to the welding of mild steel is a true "Diamond in the Rough." To the writer who has been privileged to conduct very extensive experiments in this field during the past several years the first reaction on reading this paper is to say "Amen."

Commenting thereon and more particularly confining my remarks to the use of welding in the shipbuilding industry the first question to answer is; What are the so-called "Locked-Up Stresses" and how produced? Stresses are induced into a piece of steel local to a weld due to the property of steel shrinking every time it is heated and cooled. This occurs in any piece of steel every time it is heated and cooled and it is possible to convert a cube of steel into a sphere by no other means than a series of heating and cooling.

As applied to a weld there are two factors that enter into this shrink, first the weld metal deposit itself which acts similarly to a casting and second, the shrink in the parent metal adjoining the weld due to the heating and cooling of this metal by the welding process. We must, therefore, concede that welding or the local application of heat no matter how applied to a piece of steel does induce stresses into the metal in way of and adjoining the heated area. Through the use of strain gage readings we can show that the local heating and cooling to a white heat of a small area on a steel plate will induce stresses in the adjoining metal up and beyond the elastic limit and equal to any produced by welding. Similar stresses occur in steel, as Mr. Holslag states, any time we work or deform it, whether done mechanically or by the application of heat.

One of the fallacies in the question of stresses as applied to the shipbuilding industry is that these stresses are inherent only in a vessel that is joined together by welding. Stresses have been set-up in riveted construction through the use of drift pins, steamboat rackets, etc. and the local application of heat to pull and stretch steel plates preparatory to riveting equal to any set-up welding.

Mr. Holslag remarks that the working of the steel beyond its elastic limit improves its properties are correct, and we have proved this through many tests and experiments, even in the case of welded joints exposed to explosion and impact tests and stretched way beyond the elastic limit show marked improvement in the physical properties both in the weld and the base metal. However, if we view this condition from a "Locked-Up Stress" standpoint and consider a mild steel beam firmly fixed at both ends and we load it beyond the elastic limit and then remove the load we can safely say we have not harmed it (provided we have not weakened it through distortion) but if we leave the load on we certainly cannot expect to be able to add much further to our load and hence, if these locked-up stresses are really locked up when induced by welding then we would indeed have a serious problem on our hands, but these so-called "locked-up" stresses have the same characteristics as the well known "Dillinger" they refuse to stay locked up.

We call a piece of steel a solid but it is only relatively so and when we strain any portion of it through the induction of stresses such as applied by welding, it immediately begins to adjust itself and dissipate these stresses. This is not a new theory; it is a practical fact known and used by metal workers for generations in the use of aging to improve metals. We have conducted numerous tests in this field by inducing welding stresses in structure as firmly locked up as possible and through strain gage readings observing and plotting this dissipation of the stresses week by week. These curves show a very rapid reduction of stresses during the first week and then a continual but more gradual reduction on each succeeding week. Heat-treatment or normalizing to 1200° F. of course does this in only a few hours. Vibrating our structure for a few minutes with pneumatic hammer causes a quick drop in these stresses. Nature and time will cure most ailments even the grief and pains we put into steel through welding or other deformation and it is this faculty that makes Mr. Holslag's statement that all welding failures must occur in the first 24 hours a relatively correct one; however, this should not relieve us of aiding nature in the continuance of the use of proper welding procedures and designs as well as the use of the best materials and equipment possible in this great industry.

The use of the furnace for normalizing or the expedition of the dissipation of these stresses is apt to be greatly overdone and is needed only in the more complex and heavy weldments which are to be put to use without a sufficient period of time for natural aging to occur.

By S. BLICKMAN, President, S. Blickman, Inc.

Reference is made to the article by Mr. C. J. Holslag relative to the unimportance of residual or locked-up stresses resulting from welding in mild steel. It is the experience of the author that residual stresses resulting from such welding while difficult to readily measure, play an important part when added to the stresses due to loading applied to such welds. The fact, only, that a liberal safety factor is used is the only salvation against failures which might occur in many more cases due to residual welding stresses. Assuming, for example, a tank subjected to an internal pressure designed with a safety factor of 5, it is unreasonable to suppose that residual stresses play no part in so far as its safe design is concerned. The residual stress, when added to the load stress, may carry the combined stress to a point between the elastic limit and ultimate fiber stress of the mild steel. True, the final stress may well be below the ultimate stress and the structure may stand up, but at almost a total sacrifice of the safety factor.

Stress-relieving is insurance against the abuse of safety

factor. Failure to stress relieve leaves design in the realm of pure guess work.

The writer takes issue with Mr. Holslag's statement that the property of most metals and certainly that of steel is increased by continual working hot or cold. There is no question that the property of metals is changed by continued working hot or cold, but does the change in property always work in a beneficial direction in so far as design is concerned? For example, continued cold-working of mild steel, say in rolling, will harden and toughen the material, increase its tensile strength, and at the same time lower its elongation, but can we say that the property of that material has been improved by such continued cold rolling when, for example, it may be desirable to use this metal for a drawing operation or for a bending operation? A change in property due to working hot or cold is of value only when such change in property is of specific benefit to a particular design. In a mild steel weld, the property of the material in the weld itself and in the immediate vicinity of the weld is changed and the very fact that the property is changed from the original material in areas somewhat remote from the weld must induce internal stresses which play an important factor in so far as design is concerned. Stress-relieving, while not bringing the weld material or the parent material adjoining the weld back to its original properties, unquestionably brings the steel in such areas closer to its original condition than if not stress-relieved. There can, therefore, be no doubt that stress-relieving is of value.

A factor which has been apparently overlooked in the article referred to is the fact that when a piece of metal is stressed beyond the elastic limit but to less than the ultimate strength and the operation repeated, and while it is true that the piece may have its ultimate strength in tension increased beyond an unstrained piece (often at the expense of other vital properties), it does not follow that the property of such over-stressed material has been increased. Does it follow that in a design of a welded joint where loading stresses are continually fluctuating or even reversing themselves from compression to tension, that the design is improved because of locked-in stresses which may result from either hot or cold working? Would such a structure be as safe as one in which the material in the weld area is never stressed beyond the safe limit?

The effect of residual stresses when considered with loading stresses may be cumulative and is, therefore, dangerous and should and can be reduced by stress-relieving.

Referring to the concluding portions of Mr. Holslag's article, it is erroneous to assume that the heating of arc-welding performs its own testing. True, if the stretching is beyond the ultimate limit, the weld will break and may do so even if the weld is good, but what if the stretching due to welding develops stresses near the elastic limit or somewhat under the ultimate limit and the weld doesn't part, does it follow that because the weld does not part that the structure is safe? — that the weld is safe?

In so far as the author's personal experience is concerned, it has been of benefit to stress relieve welds in most types of mild steel welded structures and wherever economically and physically feasible. On certain types of design, for example, in the case of a built-up welded power press ram or plunger, the following stresses occur in the welded joints:

(1) Residual welding stresses
(2) Load stresses due to blanking, cutting or forming (In the case of special cutting operations, such load stresses may reverse from compression to tension.)
(3) Impact stresses
(4) Torsional stresses due to side thrust.

The effect of such stresses may, at times, be readily cumulative. It is readily possible to design for unit stresses under subdivisions 2, 3 and 4. It is not so readily possible to design for the stresses under Item 1. Safety factor to a large extent covers the designer against these so-called non-readily determinable stresses. Since stress-relieving does play an important factor in eliminating these residual welding stresses, it would appear economically unsound not to take advantage of stress-relieving. Why sacrifice safety factor in design by omitting stress-relieving of residual welding stresses?

By O. T. BARNETT, Metallurgist, Black, Sivalls & Bryson, Inc.

We are inclined to take the opposite point of view to that advanced by Mr. Holslag.

Figure 1 is a view of a tangential inlet we were asked to make for one of our customers. In this photograph it will be readily seen that the tangential inlet comes to rather an abrupt point between two rather large amounts of weld metal. It was this design that led to all our troubles.

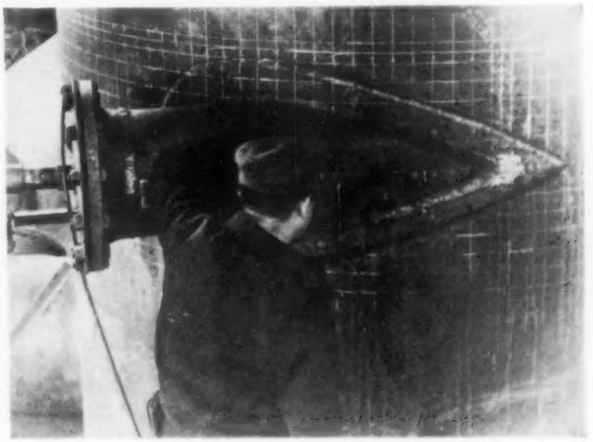


Fig. 1

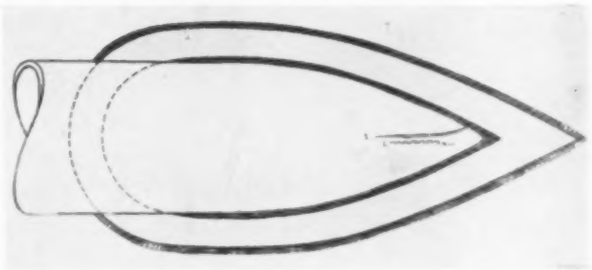


Fig. 2

After we had fabricated the first vessel with this tangential inlet in place and started to test the vessel we had a failure as is indicated in Fig. 2 with a numeral 1. This failure during test was thought to be caused by faculty material, and the material of which the tangential inlet was made was rejected.

On our second attempt to weld this inlet, we were even more careful with our peening of the weld so as to eliminate that point as the source of our trouble. The welding ran along smoothly, and again the vessel was tested. During this test a failure occurred in the portion marked with numeral 2 on Fig. 2.

It was at this point that we felt quite sure that the difficulty lay in locked-up welding stresses rather than in

faulty material of which the tangential inlet was made. With this in mind, in addition to the peening of the weld on both sides of the inlet, we heated the metal quite hot. This time no failure occurred during test.

The thought was advanced by the customer that it might be well to test the design of this vessel to see whether or not design stress was the cause of repeated failure. For this reason we placed the vessel in our stress-relieving oven (although it was not to be stress-relieved on the original specifications) and after stress-relief made some extensometer tests to determine points of maximum stress. These tests proved conclusively that the points of maximum stress were not located near the points of failure and that the only reason that could be advanced for the failure of these inlets would be locked-up welding stresses.

By W. O. BOIAN, Engineer, Pittsburgh-Des Moines Steel Company

I have carefully read Mr. Holslag's article on Locked-Up Stresses in Mild Steel Welding, and agree with him because I have felt the same for quite a long time. I also have not seen or heard of any failures resulting from locked-up stresses in mild steel welding. When it is said that locked-up stresses are not harmful, it, of course, must be understood that the welding was done by experienced welders who knew what they were doing and proper procedure to use where locked-up stresses might become harmful.

I do not know how this question can be conclusively settled except by the fact that we don't have any failures is probably the best test that can be resorted to.

I have seen circular manholes with a flange welded to the lower ring of an oil tank. A stress of 22,000 lbs. per square inch determined the tank plate thickness. After the circular manhole had been welded on, considerable shrinkage resulted, which caused the tank plate to warp inwardly. After the tank was filled with water for testing, the plate did not stretch out to the same cylindrical form as the remainder of the plate that had not been welded, and there was no failure.

Apparently steel can absorb more abuse than they give it credit for.

By O. A. TILTON, Welding Engineer, General Electric Co.

I quite agree with Mr. Holslag in, what is evidently his intent, to show that locked-up stresses certainly exist in welded structures, as well as in those fabricated by other means but that they do not constitute any serious or logical obstacle to the use of the process. In fact, it is my personal opinion that the nature of these stresses as well as the means of avoiding difficulties due to them is very well understood in the industry today. Therefore, I cannot see exactly why Mr. Holslag should get particularly disturbed, as he seems to be in this article. The truth of the matter is that those who fail to use welding because of a fear of the locked-up stresses resulting from the localized heating inherent in the process, are very much in the minority. They represent a group which in effect admits either:

(1) That they are ignorant of many of the principles commonly known by steel makers and fabricators.

(2) That they have an axe of their own to grind.

(3) That they are just too stubborn to adopt new ways to make money.

Would it not be better wisdom on our part to let these few die-hards work out their own salvation or be trampled down by their more progressive fellow craftsmen. Could we not with much more profit to the industry as well as ourselves devote our attention to the perfection of welding fabricating processes, equipment and designs, rather than struggling with this ineffectual minority. It has been said, "A woman convinced against her will is of the same opinion still." I wonder if this doesn't apply to self-styled engineers, in many cases, just as well as to the dear sisters. If so, they can be won over from the angle of envy of another man's profits, which we can help to increase by encouraging him in his more progressive attitude to this new tool of industry.

I would certainly not advocate, nor do I believe it is Mr. Holslag's intent to do so, that we deny the existence of stresses due to welding. On the contrary, however, we should know their nature, their cause, their effect and how to counteract them. These things are common knowledge today and in common practice as well.

By E. H. EWERTZ, Electric Boat Co.

It is both interesting and refreshing to read statements made by Mr. Holslag regarding what he and many others call "locked-up" stresses in welded construction.

Remembering that metals are fluids of varying density and that it is the flowing nature that permits pressing, for instance, sheet steel into suitable form for automobile bodies, or spinning of sheet metal into many odd forms, producing a finished metal part that is stable and useful with strength equal or better than the original sheets, although possibly harder or less ductile. Now in such operations it is evident that a certain portion of the metal sheets has been worked more than other portions, but the fluidity takes care of this difference by adjustments of atoms so that in time the whole metal part is again neutral or of the same nature throughout.

We know that metal heated in any manner on cooling contracts in proportion to the degree of heat applied, but here again its fluidity, while accelerated in the heated zone, still causes a flow even some distance away from the heated zone, as seen when tests are made and stress readings are taken. It has also been demonstrated that this flow causes the original created stresses to diminish week after week, and a neutral condition is reached after a few months, even in parts that are held rigid or unmovable. The flow can be accelerated by rapid vibrations or by heating the whole to a relatively low temperature, and such procedure may be desirable when mass is small relative to numerous heated zones, particularly if the finished part is to be highly stressed before the required normal seasoning period.

Every possible assistance should be given Nature by the designer, such as a procedure of construction, proper form and time for reaction. Obviously, no more heat or no larger welds, nor any more of them should be used than necessary.

In conclusion, it must be evident that considering the nature of a weld, if we design the welded structure in proper manner and construct it with suitable procedure and with qualified mechanics and allow time for stress flow, we will harvest a satisfactory and safe finished product free from all construction stresses.

By R. E. CECIL, Wm. B. Scaife & Sons Co.

I think Mr. Holslag has taken a grain of truth and stretched it to an unreasonable limit.

The reason this is a controversial subject, in common with all controversial subjects, is because there is no preponderance of evidence either way.

In the early days of poor or bare wire welding we all experienced a great deal of trouble with cracked seams and some simple structures simply could not be welded. Since the advent, however, of better welding rod with heavy coating we do not experience this cracking, however, the strains which caused the cracking are still present

100% but the ductility of the weld prevents cracking and of course also reduces stresses. As I see it, right here is the controversial point, nobody knows exactly "how much" the stresses are reduced.

We know that all of our formulae and calculations fall down when we reach the point of plastic flow, or exceed the elastic limit. We have a redistribution of stresses but just how much the maximum stress may be reduced below the elastic limit (if any) I do not know, but I am personally convinced that there are often locked-up stresses of some undetermined magnitude. I can agree that as a vessel becomes older and there are variations in temperature, or pressure, or vibration, there is some kind of a molecular rearrangement which does reduce these stresses but again I do not know "how much." I have run some tests which indicate to me that such is a fact.

By GALEN H. MOORE, JR.

Considerable of Mr. Holslag's statements in connection with locked-up stresses, caused by welding, concern average conditions and general results; and when it is realized that weld failures are very few in comparison with the great amount of welding we are doing, we may in general accept the theme of his statements. However, under certain conditions, welded joints, welds and base metal have been demonstrated in practice to be sometimes subject to cracks and marked distortions caused by welding thermal stresses and, these undesirable happenings may occur either during or after the welding period because of excessive locked-up stresses.

Many factors are involved in successful welding design and practical welding, requiring care that we do not overlook the fact that it is possible for considerable shrinkage stress to accumulate and concentrate at a single point. When this shrinkage stress is additional to other stresses and it occurs under certain conditions, alarming results have been obtained. In one case the residual stresses in a large welded structure were added to by a drop in atmospheric temperature and a slight deflection, the summation of which caused a ripping action completely severing a large plate from which several million pounds of tensile strength had been expected. Also, a similar part had a sufficient accumulation of shrinkage stresses to cause a fracture several inches long in the center of a thick plate, which occurred under conditions leaving no doubt that locked-up stresses acted in combination with stresses caused by outside influences, all of which concentrated at a single point.

With reference to these cases, another and similar structure had considerable service of a severe character with no indication of failure. A close comparative analysis of each case showed that ample movement occurred during welding on the satisfactory structure and that a rigid condition with very little movement existed during welding of the structures that failed. Rigid type joints, such as patch plates butt welded into a heavy plate, require considerable care to successfully complete. Therefore, judging from these and other examples it appears entirely correct to assure ourselves that welding residual stresses should be kept to a minimum.

Procedures for ship erection welding are developed with the purpose of permitting as much movement as possible during welding operations, in order that an accumulation of shrinkage stresses and excessive distortion will reach neither a critical condition nor concentrate to a maximum condition at any point. As stated before, many variable factors enter into the making of welds, and our insufficient knowledge of locked-up stresses is likely to cause undue and unnecessary misapprehensions (probably due principally to all factors not having been properly proportioned and considered). We should by all means develop accurate data and rules for control of locked-up stresses and distortion. Where distortion and movement occur to a maximum extent the evidence is that locked-up stresses are at a minimum, and conversely we also have good reasons to believe that minimum distortion and movement is accompanied by maximum residual stresses. When distortion is avoided and the movement does not occur for mechanical reasons, peening and stress-relief are employed to reduce the residual stresses that result, although these methods of relieving stress may not always be necessary.

In conclusion, considerable experience and judgment are necessary at the present time when analyzing the factors that contribute to residual stresses and distortion; along with prediction of their effect on the service performance of a structure. This should not cause any consternation, because results have yet to be based on mathematically accurate data.

By HARRY C. BOARDMAN, Chicago Bridge & Iron Co.

The author's statements are succinct, thought-provoking, and somewhat irritating. They express partial, not whole truths, and give an impression of cocksureness which is not fully shared by the welding fraternity. Assertions that "there are *no* harmful locked-up stresses in mild steel welding," and ". . . . . and aging occurs in mild steel *completely* eliminating *all* stresses," cast suspicion upon the rest of the paper.

Nevertheless, there is much to support him. He admits, as all welding engineers must, the existence of locked-up welding stresses, but denies that they are harmful in mild steel provided no cracks occur under test, or in the first few hours of service. If this were not largely true, many structures now in service would long ago have failed.

Hundreds of large field-welded unfired pressure tanks for noncorrosive liquids and gases have been built without stress-relieving by heat, and not one, to the writer's knowledge, has developed cracks in service, although cracks in some appeared during welding and testing. These vessels testify to the effectiveness of mechanical stress-relieving.

Rolled sections, as received from the mill, can readily be shown to have locked up in them very high stresses, which are commonly ignored in designing. Non-uniform rolled sections curve as they cool, and are straightened cold without noticeably harmful results.

If an unstress-relieved section be built up of several pieces welded together and tested as a column alongside a rolled section of the same cross-sectional area and length, it will be found to fail at approximately the same load as the rolled section, although in it initially are locked-up stresses at or near the yield point. The parts which are under initially high stress deform plastically under relatively small loads, and just prior to failure are stressed little, if any, more than the rest of the section. The plastic range is a great equalizer.

The same reasoning accounts for the fact that existing structures, particularly bridges, are often reinforced by welding new pieces to the old members, and with complete success, although the maximum stresses in the old members immediately after reinforcing are probably greater than they were before. These stresses unquestionably reduce in service.

Plates as received from the mill are, as a matter of course, rolled and dished, or otherwise formed while cold, and then joined to operate under loads which take

no account of the obvious fact that portions of the plates are initially stressed beyond the yield point.

More and more ships are being satisfactorily welded and operated, yet they are not stress-relieved by heat, although they are unavoidably subjected to the buffeting, racking and twisting of waves and machinery.

Fatigue tests of welded joints have not conclusively demonstrated that locked-up welding stresses appreciably lower the fatigue strength. In many cases, a few load cycles appear to have greatly reduced the initial stress irregularities.

If objectionable distortions appear during the welding of an assembly, they are often removed by a judicious process of localized heating and cooling, which probably results in higher locked-up stresses than existed while the deformations were at their worst, but if cracks do not develop soon after the straightening is done, there is no hesitancy in putting the assembly into use under the loads for which it was designed.

Machinery housings made of plates 3 to 4 inches thick can be successfully welded without stress-relieving by heat, so that they will give a good account of themselves in service. However, unless the welding is carefully balanced, or else heat treated, such housings will sometimes deform so much while being machined as to make them inoperable. This fact alone demonstrates the reality, not the fictional quality, of internal stresses.

Without sufficient supporting evidence, the writer believes that local irregularities, such as slag inclusions, undercutting and abrupt changes in thickness, contribute more to fatigue failures than do locked-up welding stresses.

Parallel tests of Par. U-68 and Par. U-69 vessels designed for the same pressure would be quite informative, especially if three vessels of each type were first made and tested according to the A.S.M.E. Unfired Pressure Vessel Code, and then a steadily increasing pressure applied to each until failure; then, three more vessels of each type were made, code-tested and then subjected to breathing tests to failure; and, finally, three more of each type were made, code-tested and subjected to a drop test while full of water. The nozzle connections would require very careful consideration.

If the Par. U-69 vessels compared favorably with the Par. U-68 vessels under the foregoing tests, the tests should be repeated, making the Par. U-69 vessels of the same thickness as the Par. U-68 vessels.

The Engineering Foundation could, in the writer's opinion, do no greater service to the welding industry than to promote such tests, because they would be more convincing and conclusive to most engineers than tests on small laboratory specimens ever could be. The writer believes that they would largely substantiate the views of the author, but, contrary to him, urges a continued investigation of locked-up welding stresses by all available means to determine when they are dangerous, and when they can be safely ignored, what causes them, and how they can best be reduced or eliminated. Even the author would not claim them to be in any sense beneficial or desirable.

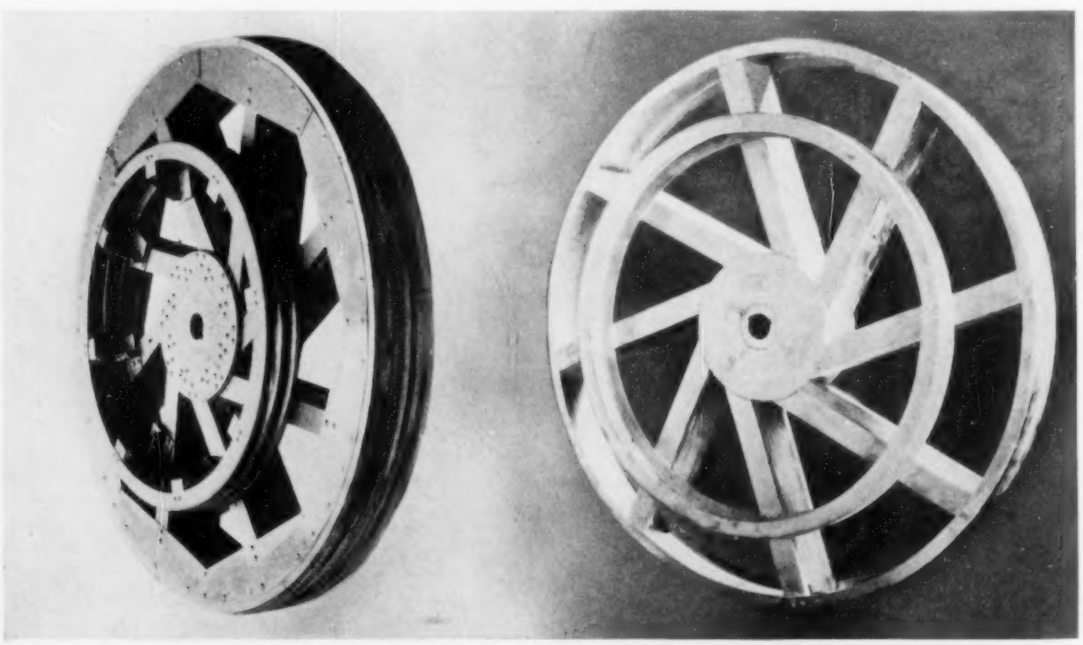
Wheels

By A. F. DAVIS†

THE two wheels illustrated are both bandwheels. The one on the left is extremely complicated, containing a great number of miscellaneous component parts all joined together by rivets. The one on the right is entirely of steel and is made simply by cutting standard steel shapes and plates to correct size, and fusing them together into a single unit by electric welding. The outer rim is composed of three sections of channel shapes. The spokes consist of two channels and a piece of plate. The hub is a piece of tubing with keyways cut into it and welded to a circular piece of plate. The tug rim (the smaller wheel) is simply four pieces of grooved channel shapes welded to the spokes of the larger wheel.

The wheel illustrated is 11 ft. in diameter and was fabricated entirely by electric welding by Steel Products Company of Iola, Kansas.

† Secretary, The James F. Lincoln Arc Welding Foundation.



What Happens in the Welding Arc*

By S. C. OSBORNE†

WE assume that you have all had some contact with welding and know what an arc looks like. It is caused by forcing electricity to flow through a gaseous medium between the closely spaced terminals of an electric circuit. Since it is intensely hot, the terminals of the circuit adjacent to the arc also become hot. These terminals of the circuit are called the electrodes; one of which is generally the work, and the other either a metallic wire or carbon rod. When a metallic electrode is used, both the work and the electrode are melted. The molten material from the electrode is carried across the arc and deposited on the work. Thus, the electrode provides additional material to form the joint. When a carbon electrode is used, only the work is melted and any additional metal required must be supplied in the form of a filler rod as in gas welding. The carbon electrode is slowly consumed by evaporation and oxidation.

Have you ever stopped to consider why an electric arc is so effective for welding? Our first thought is the high temperature. Some observers have recorded arc temperatures as high as 10,000° F. which is obviously considerably higher than required to melt steel. This, however, is only part of the story. What is more important, the arc produces the greatest concentration of heat energy known to man. For example, with a one-quarter inch steel electrode, the average arc voltage and current are about 30 volts and 250 amperes. Thus, we have 7.5 kilowatts or 10 horsepower concentrated in a volume smaller than a lead pencil eraser.

It is this tremendous concentration of energy which makes it possible to melt such a very small volume of metal along the edges to be joined.

An extensive knowledge of electricity is not necessary to the application or conduct of welding operations, but a grasp of the fundamentals of electric current flow will be found helpful.

The leading scientists now conceive electricity and matter to be intimately associated. Thus, we are told that the smallest particles of both electricity and matter are negatively charged electrons and positively charged protons. An atom is thought to consist of a predominantly positive closely knit cluster or nucleus about which are grouped a number of negative electrons. These electrons are relatively free to move and normally circulate or oscillate about the nucleus. The atoms of the various substances differ from each other in the number and grouping of electrons and the degree of their freedom.

Under certain conditions, these electrons may be detached from the atom and caused to move or flow independent of the nucleus. It is this flow of electrons which constitutes an electric current.

Electricity can be made to flow through any substance but some permit the electrons to flow relatively easily while others allow almost none to pass through them. Those which pass electricity easily, such as copper, aluminum, steel and other metals, are called electric "conductors." Those which prevent the passage of electricity, such as dry paper, rubber, cotton, glass, fiber, bakelite and air, are called "insulators."

Since electricity acts like an incompressible liquid (such as water) it can best be explained by analogy to hydraulics. Thus, pressure is acquired to force water through a pipe. So, too, with electricity pressure is required to make electrons flow through a conductor. Electrical pressure is called electromotive force or potential, and, while hydraulic pressure is measured in pounds per square inch, electrical potential is measured in volts. The rate of flow of water is measured in cubic feet or gallons per second, while the electrical rate of flow is measured in amperes. The flow of water through a pipe is retarded by friction with the walls of the pipe and the electron flow is also retarded by what is known as resistance. Electrical resistance is measured in ohms and is dependent upon the material of the conductor, its cross section and length.

Thus, we have described the three basic electrical units:

1. The *volt* is a unit of electromotive force or potential corresponding with pressure in hydraulics.
2. The *ampere* is a unit of electrical rate of flow or current corresponding to gallons per second in hydraulics.
3. The *ohm* is a unit of electrical resistance corresponding to friction in hydraulics.

It should be noted that in each case, these units are a measure of some property of electricity in motion, but are not a measure of quantity of electricity.

The relation between these three properties may be stated as follows: $E = IR$ where E is the symbol for electromotive force in volts, I is the symbol for current in amperes and R is the symbol for resistance in ohms. This is known as "Ohm's Law." Such a relationship could also be stated for hydraulics, but it could not be used in this simple form because the rate of flow and friction are not easily measurable and are quite variable. Electrical quantities and relationships are simpler to handle numerically because they can be easily and accurately measured, and the electrical resistance of most conductors remains practically constant under normal conditions.

So far we have discussed only the passage of electricity through conducting materials, such as metals. In the arc, however, it must pass through a gas which is normally a non-conductor. As has been pointed out, free electrons are necessary to the passage of any electric

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* Presented as Lecture No. 1 of New York Section Lecture Course at Brooklyn Polytechnic Institute.

† Chief Engineer, Wilson Welder & Metals Company.

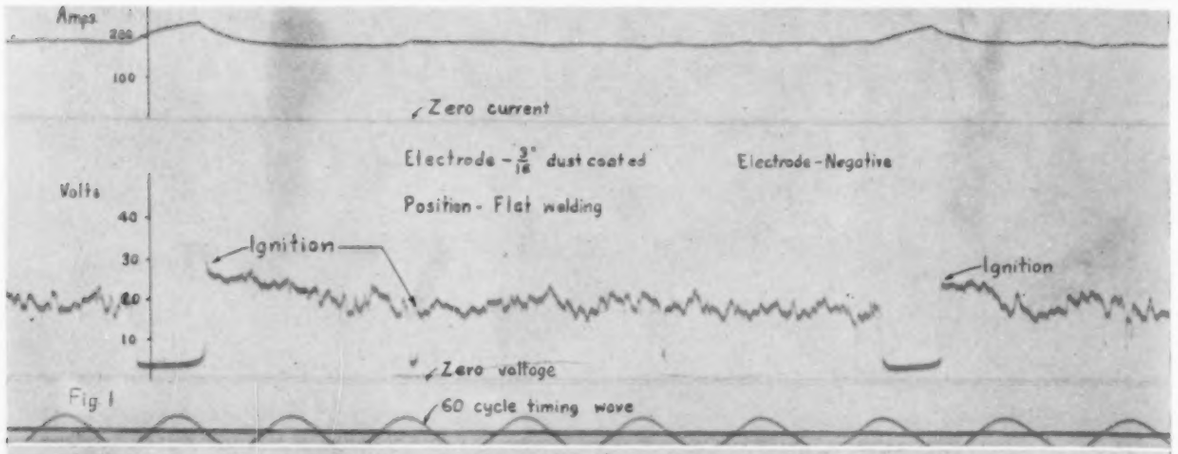


Fig. 1

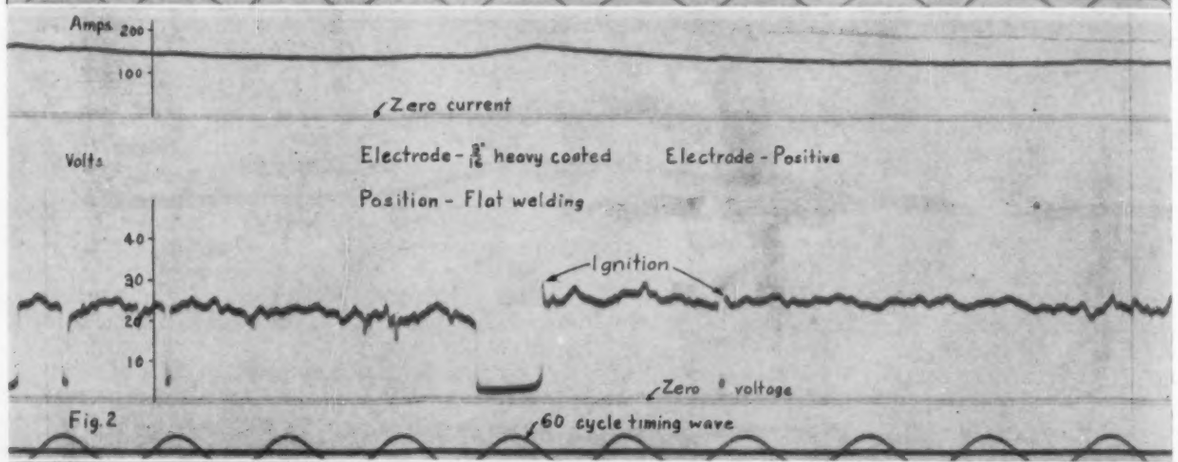


Fig. 2

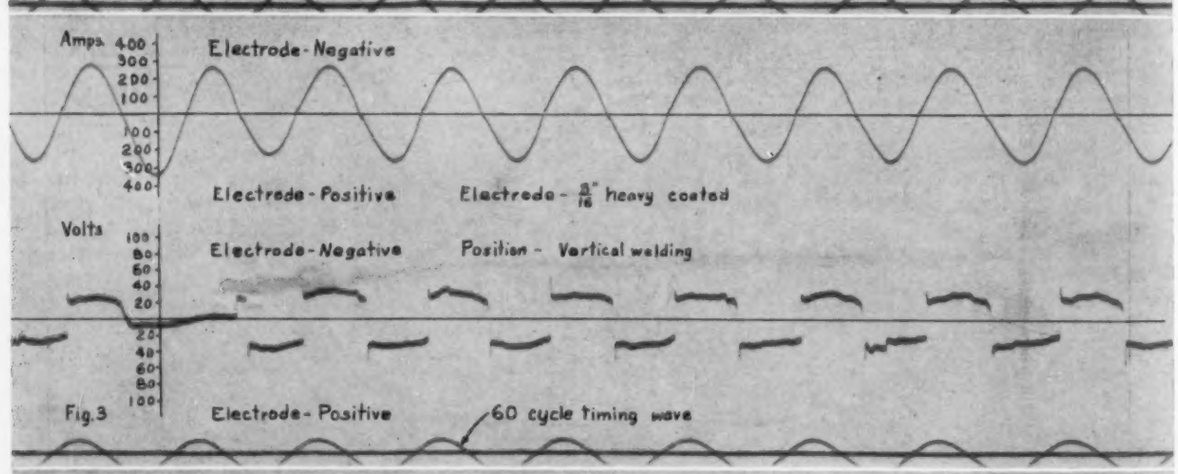


Fig. 3

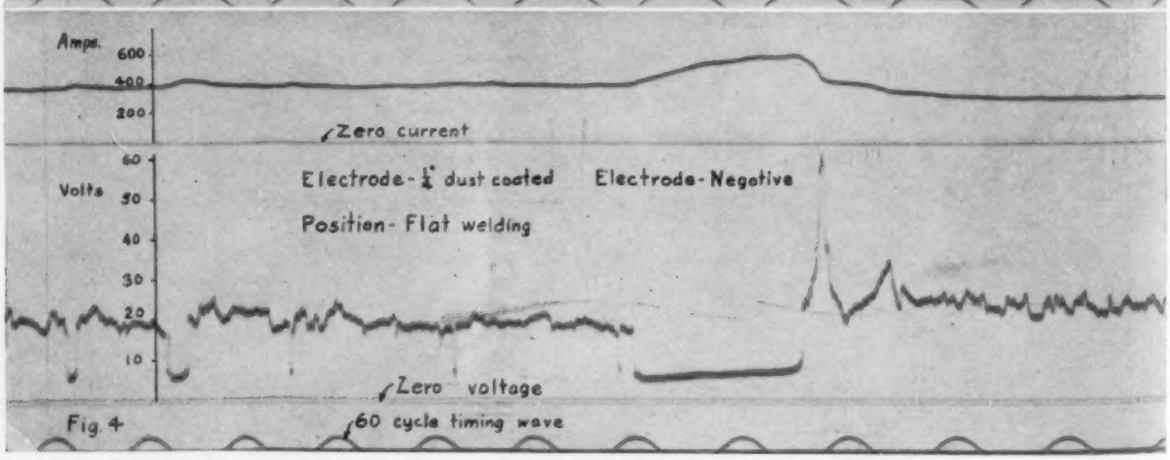


Fig. 4

current. The process of breaking down the atoms of a gas to provide free electrons for conduction is called ionization. This can be accomplished in several ways. First, by raising the voltage to a very high value so that the electrical stress is sufficient to pull the electrons away from the positive nuclei. This can be more readily accomplished at high temperatures since the voltage required decreases as the temperature increases. Second, if a free electron moving at high velocity passes near to, or collides with an atom, it may force other electrons away from the nucleus. Third, when conducting materials are heated to incandescence, free electrons escape from the hot surface. This is called thermionic emission. When it takes place in the presence of an electrostatic field, the electrons thus freed are given high velocities in the direction of the electric field, collisions occur and ionization is thus rapidly accomplished. To strike the welding arc, the electrode is first touched to the work. This short circuits the electric circuit and the resulting heavy current flowing through the high resistance contact between the electrode and the work rapidly brings the end of the electrode and the contact point on the work up to incandescence. These incandescent points emit a large number of electrons, so that when the electrode is again separated from the work, the air between them is readily ionized and the arc formed.

As has been indicated, the resistance of the arc stream varies with the temperature. This has been explained by Dr. C. G. Suits as due to a balance between the numbers charged and neutral particles in the gases. Thus, the proportion of charged particles increases as the temperature increases and the resistance decreases. You have probably noted that once the arc has been formed, it is quite easily restarted after an interruption. This is due to the presence of hot residual gases between the electrodes and the ease of restriking will depend upon how much these gases are allowed to cool.

Figures 1, 2, 3 and 4 are oscillographs of the arc voltage and current taken while welding. These graphs are made by moving photographic paper past a slot through which shine beams of light. These beams of light are made to move in response to changes in the voltage and current values. The record thus formed is a plot of voltage and current against time. It will be noted that the voltage trace is quite saw-toothed. This is an indication of minor temperature variations. The points marked "Ignition" indicate the excess voltage required when the gases start to cool after the arc is interrupted. Figures. 1, 2 and 4 were taken with direct current and Fig. 3 with alternating current.

As has been stated above, most ordinary metallic conductors have a constant resistance value under normal conditions. Thus, from "Ohm's Law" the current passing through an ordinary conductor is directly proportional to the voltage applied. The volt-ampere curve is a straight line starting at zero voltage and current and sloping up to the right so that the voltage increases as the current increases. The resistance of the arc, however, varies with the temperature and since it is a gaseous conductor, it is free to change its cross-section area. Thus, it has what is called a negative resistance characteristic and its voltage decreases as the current increases, see Fig. 5.

If a constant voltage source of electric power were used for arc welding, the current would increase to a dangerously high value. It is, therefore, necessary to use a self-regulating source of power having volt-ampere characteristics such as shown in Fig. 6.

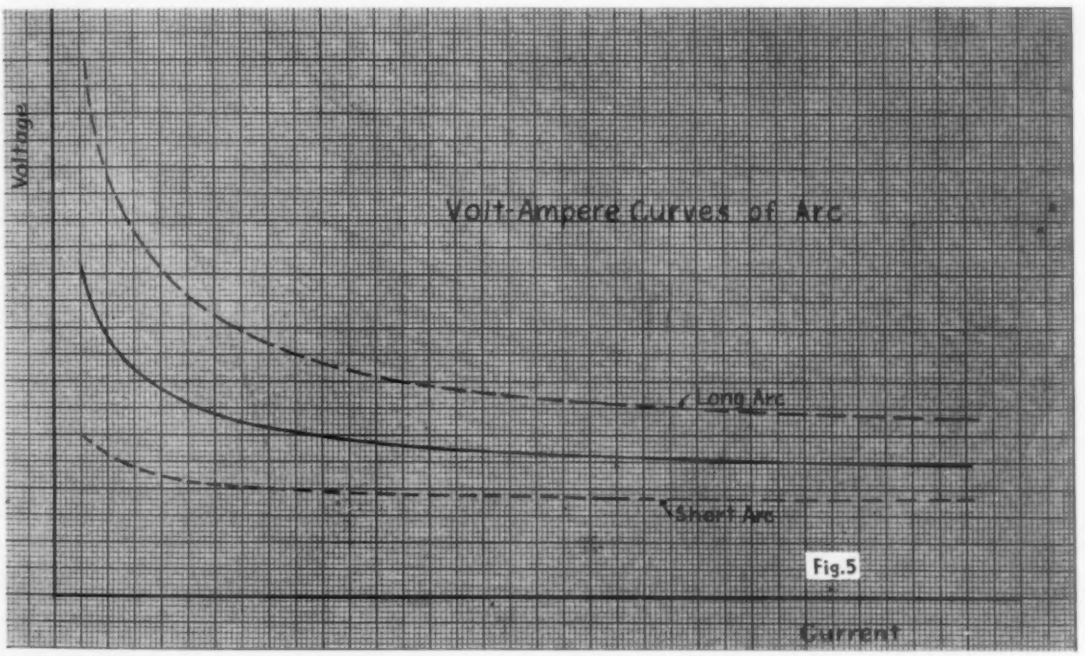


Fig.5

With ordinary metallic conductors of uniform cross section, the voltage distributes itself uniformly along the length of the conductor, and a voltage measurement between two points a given distance apart would be the same for all parts of the conductor. The voltage across an arc, however, is not uniformly distributed but is greatest at the surface of the electrodes. We, thus, have three voltage zones: the "Anode Drop" (at the surface of the positive electrode), the "Cathode Drop" (at the surface of the negative electrode) and the "Arc Stream Voltage." The anode and cathode voltage drops occur in infinitely thin skins at the surface of each electrode. Together, they amount to between 10 and 13 volts and remain constant independent of the arc length or current. The anode drop is generally larger than the cathode drop and accounts for the fact that the anode is generally

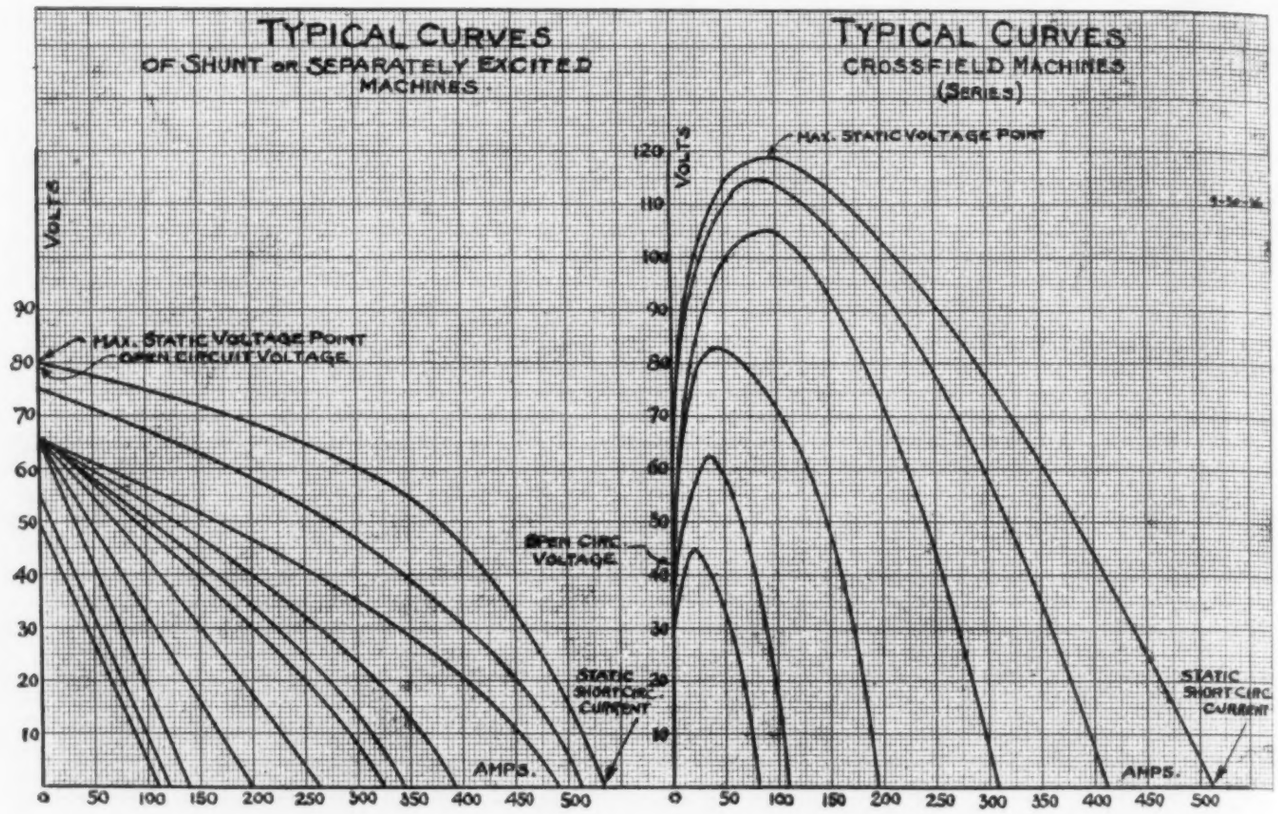


Fig. 6

the hotter side of the arc. The arc stream voltage is uniformly distributed between the electrodes and varies with the arc length and current.

Since the energy distribution must be the same as the voltage distribution, we have three distinct thermal zones in the arc. The temperatures at the surface of the electrode and work must be limited to the boiling point of the metal in question, but since energy is also dissipated in the arc stream, its temperature may considerably exceed those at the surfaces of the electrodes. As pointed out above, very high temperatures have been recorded for the arc stream.

Since a large part of the voltage across the arc is independent of the arc length, a small change in arc voltage will result in a large change in length. Thus, a 24-volt arc is approximately twice as long as an 18-volt arc.

As has been pointed out with metallic arc welding a large part of the metal in the joint is deposited from the electrode. The manner in which metal transfers across the arc is not clearly understood. While aided by gravity, it is not dependent upon gravity since steel can be deposited overhead. With bare or light-coated electrodes, most of the metal is transferred by globular formation. This method of transfer is undoubtedly aided by the pinching effect of the magnetic field around the arc which has a tendency to squeeze the molten globule across the arc in much the same manner that a baker squeezes his frosting bag when decorating a cake. With shielded arc electrodes, the globular formation is much less frequent and Dr. L. J. Larson, in his paper "An Exploration of a Modern Welding Arc," has shown that most of the metal is transferred in a finely divided state aided by the very large volume of gas generated by combustion of the coating. Independent of all these effects, however, there is evidence that metal transfer across the arc is primarily a thermal effect, since it is impossible to transfer metal from one electrode to another when both electrodes have about the same cross section. In order to effect transfer of metal, one electrode must be considerably larger than the other and the transfer is always from the smaller to the larger electrode.

The fluxes used in other forms of welding generally perform the function of merely dissolving or reducing the oxides and other impurities so that the metals can more readily unite to form the weld. They may also contain materials which make the weld metal more fluid.

The coatings on arc welding electrodes, however, are more than just fluxes in that they perform a number of other important functions in addition to those just mentioned. In general, they serve any or all of the following functions:

1. To dissolve or reduce impurities, such as oxides, sulphur and phosphorus, and thus keep them out of the weld.

2. To make the flow of metal across the arc more uniform, by reducing the adhesive force between the molten metal and the end of the electrode or by changing the surface tension of the molten metal so that the globules of molten metal, leaving the end of electrode, are smaller and more frequent.

3. To increase the arc stability by introducing materials which are easily ionized in the arc stream.

4. To produce a reducing or non-oxidizing atmosphere around the arc which will prevent contamination of the metal in the arc by oxygen and nitrogen from the air.

5. To provide a slag which will cover the molten metal in the weld pool and thus prevent contamination by oxygen and nitrogen from the air. This slag is quite refractory so that it holds the heat and thus allows the metal to solidify and cool slowly. The slow solidification permits solid impurities to float to surface of the molten metal and allows dissolved gases to escape. The slow cooling has an annealing effect on the weld metal.

6. To form a cup or cone around the end of the electrode which acts much like a crucible providing a mechanical shield, concentrating and directing the arc, reducing the thermal losses and increasing the temperature on the end of the electrode.

7. To introduce materials which will alloy with the weld metal and thus change its physical characteristics.

8. To insulate the sides of the electrode so that the arc is concentrated on the end of the electrode. While this is generally incidental to the character of the coating, it is important when welding in a deep kerf or V.

The coatings on bare or light-coated electrodes generally do not perform more than the first three functions, and while some of them may produce a slag, it is quite thin and does not adequately cover the molten metal or form a cone.

Shielded or heavy-coated electrodes are of two general types: those which depend entirely on slag as a shield and those which produce a gaseous shield as well as the slag. The first type must produce so much slag to get the proper protection that they are not suitable for vertical or overhead work, but produce superior results in the flat or horizontal position. The second type can generally be used in any position because the gas shield makes it possible to use less slag.

The arc of heavy-coated electrodes may be likened to a miniature electrically fired open-hearth furnace since the reactions which take place are very similar.

Arc welding is fundamentally an electric casting process and, while the weld metal is really cast metal, with the new shielded or heavy-coated electrodes, it is vastly superior to ordinary cast metals. In fact, its physical characteristics are considerably better than the best rolled or forged steels of similar chemical composition produced by the steel mills. This is probably due to the fact that it contains less impurities.

In addition to producing a superior weld, the heavy coatings permit the use of more current for a given diameter electrode, and the arc voltage is higher than can be used with bare or light-coated electrodes. Thus, with more energy in the arc, the welding speed is as much as 200 per cent to 400 per cent higher.

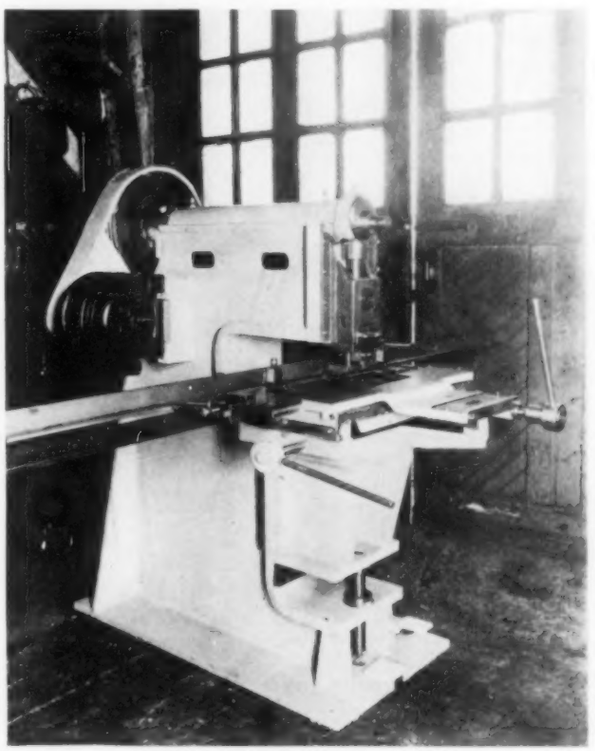
All Steel Deep Throat Presses

By K. S. BURDITT†

OUR Company manufacturers of special production equipment for sheet metal shops, are introducing a lighter weight series of deep-throat adjustable bed power presses, having all steel welded frames and welded steel adjustable knee beds.

When used in conjunction with the nibbling attachment illustrated, a small light weight flywheel is furnished which, together with the high speed clutch and the ring oil bearings regularly furnished with this line of presses permits of an operating speed up to 175 strokes per minute. This high speed makes it possible to clamp a piece of formed molding or trim on the nibbler table and cut an opening for hardware or similar fixtures almost as fast as could be produced with a special purpose blanking die.

Operating experience has shown these nibbling attachments can be removed from the press as quickly as a regular set of dies, making the machine readily available for all classes of punch and die work. A larger diameter flywheel is available for these presses where a somewhat lower speed and greater stored energy are required for heavier class work. Eccentrics may also be replaced readily for one of another throw where changes of stroke are desirable. All clutches furnished on these type presses are provided with safety, non-repeat feature for operating standard dies. By the turn of a button this can be disengaged and the treadle latched down for work with the nibbling attachment.



Welded Press

† Treasurer, Service Machine Company.

The Application of Welding to Large Steel Tanks*

By HARRY C. BOARDMAN†

LARGE steel tanks, usually of A. S. T. M.-A10 or A. S. T. M.-A7 material, are now welded manually, and nearly always with direct current. The operator, with a protecting hood over his eyes and face, and heavy gloves on his hands, clasps a holder with which he supports and guides an electrode connected by a cable to an electric generator, which may be either gasoline or motor driven. The circuit is usually completed through the steel structure and the ground.

If the electrode is joined to the negative pole of the generator, the welding is said to be done with *direct polarity;* if to the positive pole, with *reversed polarity.* Modern generators can be changed from one polarity to the other by merely throwing a switch. Some electrodes work best with direct polarity; others with reversed polarity.

To start welding, the operator touches the end of the electrode to the steel to be welded, and then draws it away a short distance so that an electric arc forms and joins the electrode and the steel. The heat developed at the end of the electrode causes it to melt, and drops of molten metal move in the arc stream to the places in the seam where the guiding hand of the operator directs them. As the electrode melts, the operator moves his hand toward the steel to keep the proper gap.

The voltage necessary to maintain the arc varies with the gap, but the rate of melting is practically independent of voltage and dependent on amperage alone. Generators are now so designed that the arc length, and therefore the voltage, may be varied considerably with but little change in amperage, thus making it possible for an operator to maintain a nearly constant melting and deposit rate, even though his hand be unsteady, and welding conditions poor.

The heat of the arc and of the deposited weld metal melts the edges of the plates to be joined, and the molten weld metal and the molten plate metal intermingle, and are bonded together when they cool.

During the heating period, the hot metal is largely prevented by the cooler adjacent plate material from expanding, except at right angles to the plate. The heating, therefore, causes a thickening of the plate, and the subsequent cooling results in shrinkage stresses, which are frequently nearly up to the yield point in the direction of the joint, and at right angles to the joint vary in magnitude depending upon the degree of restraint of the parts being joined.

The intensity of welding stresses may be reduced by giving the parts freedom of movement during welding; by welding in short steps or increments so that the shrinkage strains of the steps are not cumulative; and by a judicious use of peening. Eventually, there may come into general use special electrodes producing a weld metal having an appreciably lower modulus of elasticity than the plate material. Such electrodes have been developed in Germany, and it is claimed that the residual stresses after welding with them are negligibly small.

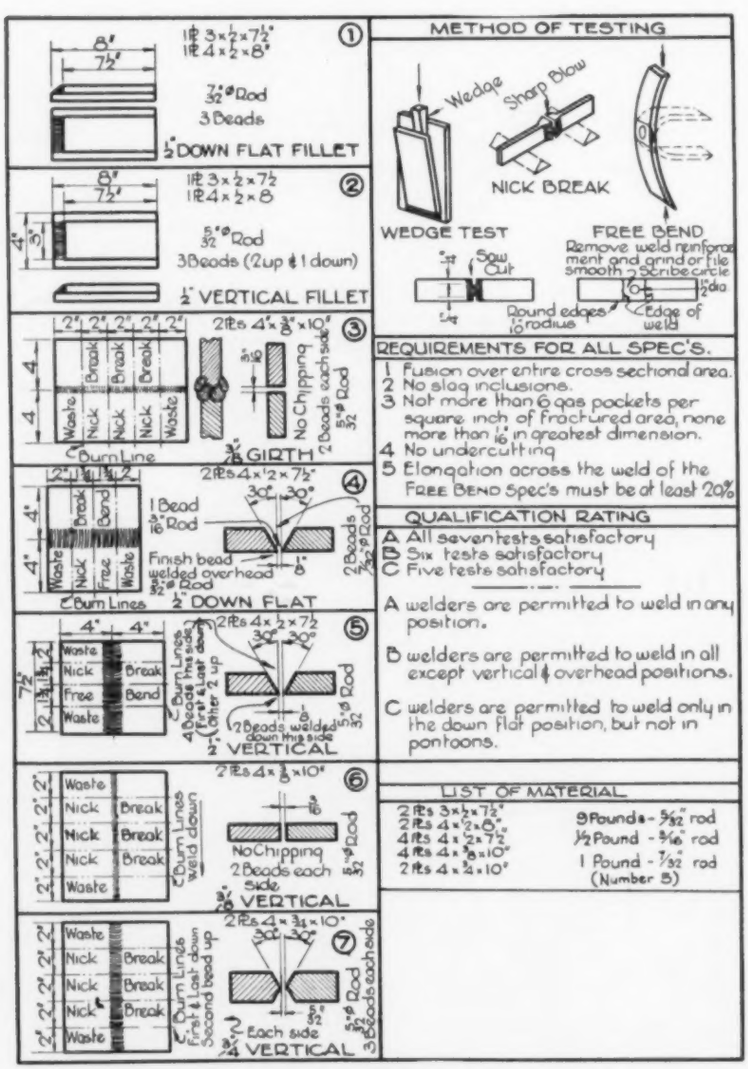

METHOD OF TESTING
Wedge
Sharp Blow
NICK BREAK
WEDGE TEST
FREE BEND
Saw Cut
Round edges to radius
Edge of weld
REQUIREMENTS FOR ALL SPEC'S.
1 Fusion over entire cross sectional area.
2 No slag inclusions.
3 Not more than 6 gas pockets per square inch of fractured area, none more than 1/16" in greatest dimension.
4 No undercutting
5 Elongation across the weld of the FREE BEND Spec's must be at least 20%
QUALIFICATION RATING
A All seven tests satisfactory
B Six tests satisfactory
C Five tests satisfactory
A welders are permitted to weld in any position.
B welders are permitted to weld in all except vertical & overhead positions.
C welders are permitted to weld only in the down flat position, but not in pontoons.
LIST OF MATERIAL
2 Pcs 3x1/2x7 1/2"
2 Pcs 4x1/2x8"
4 Pcs 4x1/2x7 1/2"
4 Pcs 4x3/8x10"
2 Pcs 4x3/4x10"
9 Pounds - 5/32" rod
1/2 Pound - 5/16" rod
1 Pound - 7/32" rod (Number 5)
1/2 DOWN FLAT FILLET
1/2" VERTICAL FILLET
GIRTH
1/2" DOWN FLAT
1/2" VERTICAL
No Chipping
Burn Line
Burn Lines
Finish bead welded overhead
Each side

Fig. 1—Qualification Tests

* Presented at Annual Meeting, Illinois Society of Engineers in Chicago, January 28th.
† Director of Research—Chicago Bridge & Iron Company.

If the electrode is a bare rod, air gets into the arc and molten metal, and the weld, though strong, is brittle, and resists corrosion poorly. If, however, the electrode is coated with suitable materials, of either vegetable or mineral base, which burn as the electrode melts, the arc by gases and the molten metal by slag, are protected from the air, and the weld metal is not only strong, but ductile and resists corrosion better than the plate itself. Heavily-coated electrodes which give these desirable results are commonly called *shielded-arc electrodes*, and it is largely to them, but partly to improved generators, that the marvelous increase in the welding of tanks since 1931 is due. Some shielded-arc electrodes are suitable for down flat welding in grooves only, others are best for fillet welding, and still others give good results in all welding positions.

Prior to 1931, much electric arc welding was done with bare electrodes on field-erected tanks, but only on accessories, and nominally unstressed parts, such as cone roofs and flat bottoms. Now, however, there is no type of field-erected tank, or part thereof, which cannot be, and which is not, satisfactorily welded in spite of the adverse conditions frequently encountered in the field but not in the shop.

The field welding operator is usually not as well supervised as his shop brother, and often the parts fit less perfectly than do pieces assembled in the shop. He necessarily leads a roving life, not conducive to the peace of mind and serenity of spirit needed for the best welding. He contends with wind, and rain, and heat, and cold, and dust, from all of which shop men are relatively free. And much of his most important work is done on vertical or horizontal seams on vertical sheets, which are harder to weld than seams on horizontal surfaces. He is also frequently tempted by a piece-work pay system to sacrifice quality for quantity. Yet, all things considered, he does a remarkably good job, as proved by the splendid service records of the many tanks which he has welded. Failures have been very few.

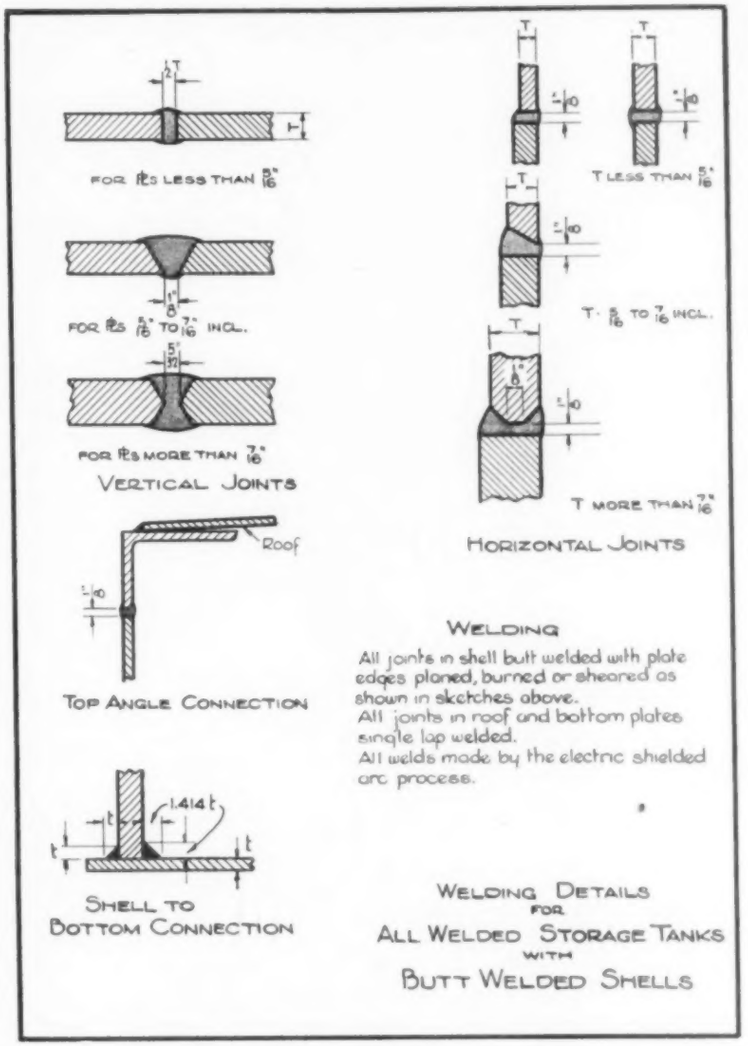

FOR t's LESS THAN 5/16"
FOR t's 5/16" TO 7/16" INCL.
FOR t's MORE THAN 7/16"
VERTICAL JOINTS
T LESS THAN 5/16"
T 5/16" TO 7/16" INCL.
T MORE THAN 7/16"
HORIZONTAL JOINTS
Roof
TOP ANGLE CONNECTION
1.414 t
SHELL TO BOTTOM CONNECTION
WELDING
All joints in shell butt welded with plate edges planed, burned or sheared as shown in sketches above.
All joints in roof and bottom plates single lap welded.
All welds made by the electric shielded arc process.
WELDING DETAILS FOR ALL WELDED STORAGE TANKS WITH BUTT WELDED SHELLS

Fig. 2

Qualification tests are an essential part of the training of a field-welding operator. Figure 1 shows a typical set of qualification tests, involving the welding and testing of seven different specimens. Specimen 1 is a lap joint welded in a down flat position. This joint is typical of lap-welded roofs and bottoms and of the fillet welds joining shells and flat bottoms. Specimen 2 is a lap joint welded with the seam in a vertical position, and is typical of lap-welded vertical shell joints. Specimen 3 is a square-butted girth joint with a gap between abutting edges. In an actual structure, this type of joint is commonly limited to plates $^1/_4$ inch and less in thickness, but good operators can weld plates $^3/_8$ inch in thickness. Specimen 4 is a single 60° vee butt joint welded with the plate in a horizontal position. The finishing bead on the apex side is welded overhead. This joint is typical of those in flat butt-welded bottoms, and in the tops and bottoms of spheres. Specimen 5 is the same as 4, except that it is welded with the seam vertical, and is typical of vertical single vee joints in the shells of oil storage tanks, standpipes, elevated tanks, spheres, etc. Specimen 6 is the same as 3, except that it is welded with the seam vertical, and is typical of square-butted vertical joints. In practice, this type is commonly used only with thicknesses of $^1/_4$ inch less, although good operators can readily weld plates $^3/_8$ inch thick. Specimen 7 is a double 60° vee joint welded with the seam vertical, and is typical of double vee vertical joints in the thicker courses of oil storage tanks, standpipes, elevated tanks, etc.

The upper right hand corner figures show the methods of testing the various specimens, and immediately below them are listed the test requirements, the test materials and the qualification ratings of the operators.

It should be clearly understood that the tests above described are for the qualification of operators, and that much more searching and comprehensive tests to qualify the materials, process and equipment necessarily precede the operators' tests, and need not be repeated unless some element in the process is changed.

The sketch for each type of specimen indicates the size of electrode, the number of passes and the direction of travel of the electrode for each pass. Different organizations have different welding procedures and types of joints suited to their particular electrodes and fabricating and erection equipment. There is as yet no fixed rule governing the conditions calling for a downward travel of the electrode on vertical joints. Generally, however, square-butted vertical joints, and $^3/_{16}$-inch and $^1/_4$-inch vertical lap joints are welded with the electrode moving downward; and vertical double and single vee or U joints are welded

with a downward travel of the electrode for the first and outermost passes, and with an upward travel for all other passes. The small initial downward pass layer forms a bridge across the gap between abutting edges upon which subsequent thicker upward pass layers may be built, and it causes relatively little contraction; the outer thin downward pass layers give the weld a good external appearance, and, to some extent, refine the upward pass layers on which they are deposited. Butt-welded girth joints are almost always made with string beads so laid that the finished weld looks as if it were formed by a number of parallel wires or strands nested in the groove.

Figure 2 shows joint details typical of flat-bottomed storage tanks with vertical butt-welded cylindrical shells and dome or cone roofs. Figure 3 shows joint details typical of the same structures with shells butt welded where the plates are over $^3/_8$ inch thick, and lap welded where they are $^3/_8$ inch and less in thickness. Both the vertical and girth joints are shown to indicate fusion throughout the entire plate thickness. Unquestionably, the vertical joints, which are highly stressed, should be fully welded, but logically, the girth joints, which are subjected to very small loads, need be welded only sufficiently to provide for corrosion, to hold the adjacent edges in line, and to provide a small reserve to withstand uneven settlement of the foundations. Nevertheless, because it is difficult to set-up inspection standards for anything less, most companies are now providing, and many purchasers now requiring, complete fusion in girth as well as vertical joints. The lone exception is the direct shell-to-bottom connection, where a fillet bead is made each side of the shell.

In lap-welded construction, on the other hand, vertical joints are commonly fully welded on both edges only if the stress requires it, and girth joints are usually continuously welded on one edge and tack welded on the other.

Under the Tentative American Petroleum Institute Rules for Oil Storage Tanks, butt-welded joints are allowed an efficiency of 85%, fully welded lap joints an efficiency of 70%, and partially welded lap joints an efficiency of $50 \times {}^1/_8 k$ per cent, when "k" is the percentage of full fillet intermittent welding on the partially welded edge. The minimum permissible value of "k" is 25%.

For welded oil storage tanks, the above joint efficiencies are applied to 21,000 lb. per square inch as a base for steels having a minimum tensile strength of 55,000 lb. per square inch or more.

For welded pressure tanks, such as spheres, spheroids and cylindrical shells with hemispherical ends, the joint efficiencies are commonly applied to 13,750 lb. per square inch as a base for steels having a minimum tensile strength of 55,000 lb. per square inch. Under the A. P. I.-A. S. M. E. Code governing the design of such vessels, the joint efficiency varies with the type of joint, the quality of material, upon radiographing, and furnace stress-relieving. Under this Code, the joints of a butt-welded vessel made of A. S. T. M.-A10 steel, which are neither radiographed nor stress-relieved, would be permitted an efficiency of only 74%. If A. S. T. M.-A70 firebox steel were used, other factors remaining the same, the efficiency would be 80%. If, in addition to using A. S. T. M.-A70 firebox material, the joints were radiographed, an efficiency of 90% would be granted, and if the vessel were both radiographed and stress-relieved, using A70 firebox steel, the design could be based on joints having an efficiency of 95%.

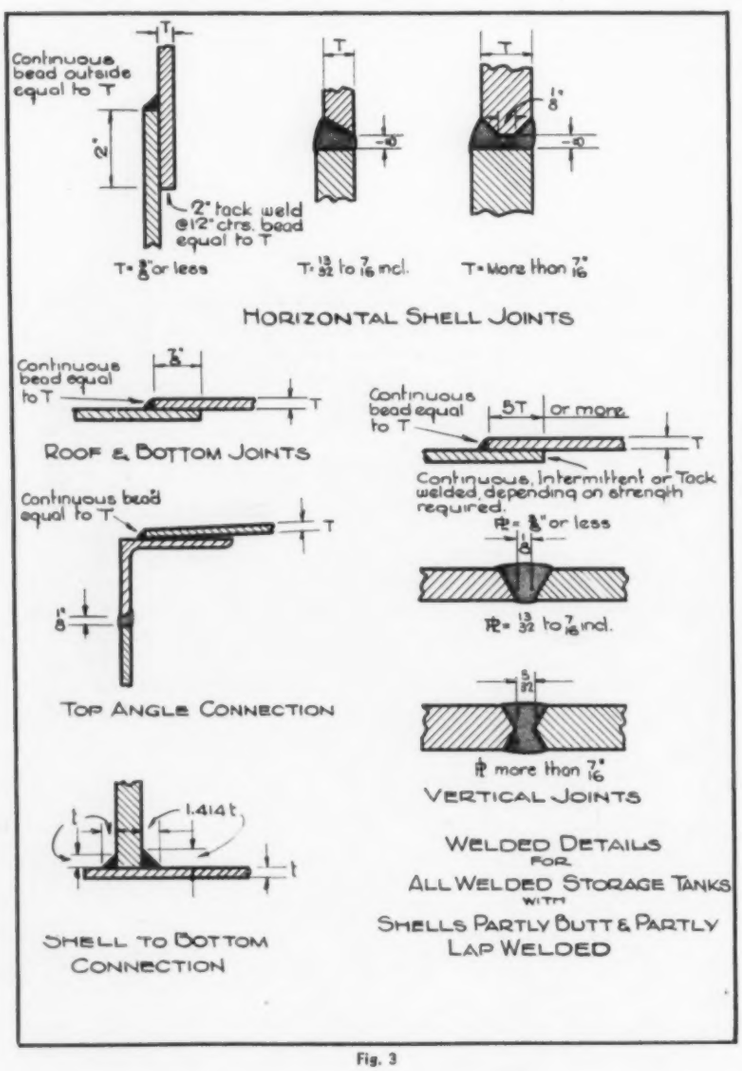

Continuous bead outside equal to T
2" tack weld @12" ctrs. bead equal to T
T = 3/8" or less
T = 13/32 to 7/16 incl.
T = More than 7/16"
HORIZONTAL SHELL JOINTS
Continuous bead equal to T
ROOF & BOTTOM JOINTS
Continuous bead equal to T
5T or more
Continuous, Intermittent or Tack welded, depending on strength required.
T = 3/8" or less
T = 13/32 to 7/16 incl.
T more than 7/16"
VERTICAL JOINTS
Continuous bead equal to T
TOP ANGLE CONNECTION
1.414 t
SHELL TO BOTTOM CONNECTION
WELDED DETAILS FOR ALL WELDED STORAGE TANKS WITH SHELLS PARTLY BUTT & PARTLY LAP WELDED

Fig. 3

Pressure vessels are almost invariably completely butt welded. For spheres and spheroids, a single 60% vee groove is commonly used. The upper half of a sphere is usually welded from the outside, against backing-up bars tack welded on the inside to one of the abutting edges; the lower half is welded mostly from the inside, but a small groove is chipped from the outside, along the apex of the vee, into good weld metal deposited from the inside, and then filled by overhead welding.

The bottoms of spheroids are commonly laid directly on the sand or earth bed prepared for them, and butt welded together from the top side against backing-up bars on the underside. The roof plates are similarly welded from the top side against backing-up strips. The side sheets may be welded from both sides, or from the outside only against bars on the inside.

Welding is rapidly replacing riveting in the large elevated tank field. Few towers have been completely welded, but many tanks proper have been welded completely, or nearly so. The methods of assembly and welding are similar to those for spheres and spheroids.

Welding has given impetus to the growing use of tubular columns.

It is well known that a welding arc struck on a cold plate often causes a crack, and that the discomfort of a welding operator when he is cold is likely to reduce the quality of his work. Therefore, for both metallurgical and humanitarian reasons, welding is usually forbidden during very cold weather. There is a wide difference of opinion as to what the limiting temperature should be. The Navy has set 20° F.; others think 0° F. is about right; and some would fix 32° F. as the limit. A small amount of preheating prior to welding is helpful.

It is no longer considered advisable or necessary to drill or punch holes in plates for assembly purposes. Devices have been developed by which plates are quickly and accurately assembled, and the gap between abutting edges adjusted to and held at the desired amount.

To avoid unsightly buckles and dangerous cracks, it is necessary that pieces be welded in proper sequence and with as little restraint as possible to normal shrinkage. For example:

The vertical joints in each shell ring of an oil storage tank are fully welded before the ring is welded to the course above and below. The vertical joints of the lowest shell ring are completely welded, and the lower edge of the ring then welded to the outer bottom plates before the latter are welded to each other or to the interior bottom plates. The interior bottom plates are next welded into sections, then the sections welded together, and finally the outer bottom plates are welded to each other and to the interior plates. If the bottom were welded into a complete disk, and then the shell welded to it, cracks along the bottom edge of the shell would probably result because the tendency of the shell to reduce in diameter as welding progressed would be resisted by the nearly rigid bottom.

The cost of radiographing field-erected vessels is now practically prohibitive. Therefore, the quality of the welding must depend largely upon suitable materials and equipment; the character, training, and mental and physical comfort of the operators; good fabrication and assembly; and adequate supervision. Trepanning cylinders of weld metal out of the completed joints at unexpected times and places has a helpful psychological effect upon the operators.

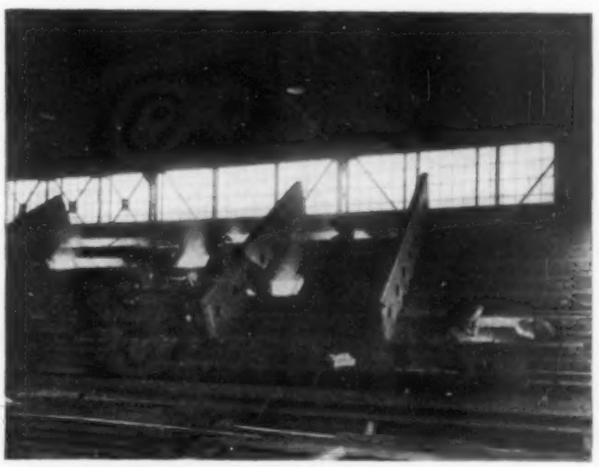
The foregoing discussion has revealed the extensive and steadily growing use of electric arc welding in large tank construction. The service records of welded tanks have proved them to be better than riveted tanks in that they cost no more—usually less, and do not develop leaks in service. The day seems near when practically all large tanks will be welded, perhaps by automatic or semi-automatic processes. The possibilities of welding challenge the imagination. None can put a limit upon them. Manual direct-current electric arc welding only has been discussed in this paper, but there are many other welding processes, any one of which may eventually displace it. Welding irresistably marches on, daily doing new things, and presenting fascinating problems for solution.

Arc Welding Cargo Vessel

By A. F. DAVIS†

GOING into many different places to join steel to steel in construction or manufacture of all sorts of structures and products . . . here, the magic of electric welding goes into a shipyard to apply the bottom plating of one of two new cargo vessels, the largest ever built on the Great Lakes by the modern electric arc process, and among the largest ever constructed by welding anywhere. Use of electric welding increases the vessel's carrying capacity 300 tons over what would be possible with less modern shipbuilding processes.

The new all welded craft is 300 feet long, 43 feet beam, 20 feet depth and powered with twin-diesel engines. They are under construction at the Great Lakes Engineering Works, River Rouge, Michigan, for operation between the Great Lakes and Atlantic seaboard via the New York State Barge Canal.



† Secretary, The James F. Lincoln Arc Welding Foundation.

Welding and Casting *not* Welding *vs.* Casting*

By H. J. SHIFFLI†

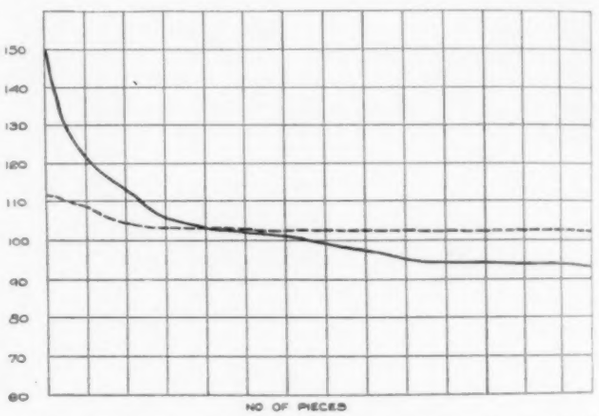
ART and science as we know it today, all had its beginning in the distant past. From the days of the ancient Egyptians down through the centuries, man has worked to discover new ways of doing things. Persistent quest for better ways to make iron led artisans of the middle ages through succeeding steps in the evolution of their industry. Bloomaries grew higher and larger, but still produced only wrought or bar iron. In the fifteenth century closed furnaces with artificial blast made their appearances in Germany and Belgium. At the beginning of the sixteenth century, the blast furnace was introduced into England. Charcoal was the only fuel used until some time in the early part of the seventeenth century when coke was made successfully. In the middle of the eighteenth century, America was well on its way in the iron-making industry. Implements of war and domesticity dominated the trade. The art of founding went hand in hand with the actual production of the iron itself in the blast furnace.

In the early part of the nineteenth century the cupola was introduced into Pennsylvania. The idea soon gained ground and its development was rapid. A short time later, steel made its entrance as an industrial product. Also, at about this time (1867) the first steel casting was produced. Twenty-four years later in the issue of "Engineering" December 25, 1891, an account was given of the successful welding of iron tubing and other objects by the heat of the electric arc.

While many have considered the gas and electric arc welding methods as comparatively new, in reality they had their beginnings in the developments of the open-hearth and electric steel furnaces. A casual study of the welding processes as compared with the furnace processes will reveal their relationship.

Today, welding represents one of the greatest single developments in the whole field of engineering technology. The novelty of welding has worn off. It is now an established method of fabrication and is finding its proper place in competitive industry. The progress made in the art during the past few years has resulted in the fabrication of many units by this method. As indicated by the recent articles in the various trade journals, its advantages are numerous; notably simplicity, weight reduction, quicker delivery, flexibility in repair work, favorable cost factor, etc. Quite naturally, enthusiasts for welding have freely predicted the early disappearance of casting from the marts of trade. However, we must bear in mind that many of the favorable features associated with the welded fabrication apply equally well to the steel casting.

Lack of precedent hindered the designer in his early attempts to produce welded structures. Usually such structures were unoriginal copies of their cast or riveted predecessors. Inadvertently, the cast-iron or cast-steel structure was merely replaced part for part with rolled steel and shapes. This resulted in nothing gainful except perhaps a slight saving in weight. Wisely, far-sighted welding engineers soon discovered that it would be necessary to devote more thought to improved design. They recognized the fact that a new medium was at hand by which they might express their ideas. Here was an opportunity to break away from tradition. As might be expected, the welding engineer swung the pendulum too far toward the exclusion of steel castings. Many designers entirely ignored the foundry's existence. Today, the consensus of opinion is that the steel casting has a very definite place in the present and future scheme of welded fabrication. In a complex structure, a steel casting can often be substituted for intricate welded shapes. The cost of a finished construction produced entirely by welding, increases directly with the number of separate pieces involved and the number of inches of



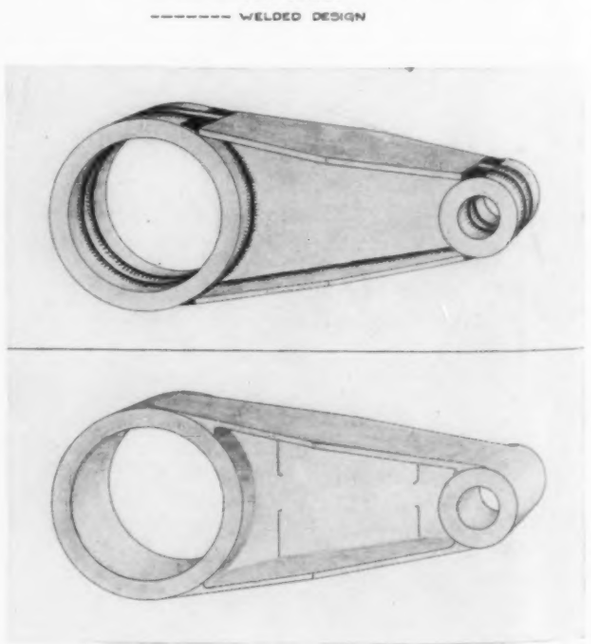


Fig. 1—Comparative Costs of Welded Designs Versus Castings

* Presented at March 19th Meeting, Chicago Section AMERICAN WELDING SOCIETY.

† Product Engineer, American Steel Foundries.

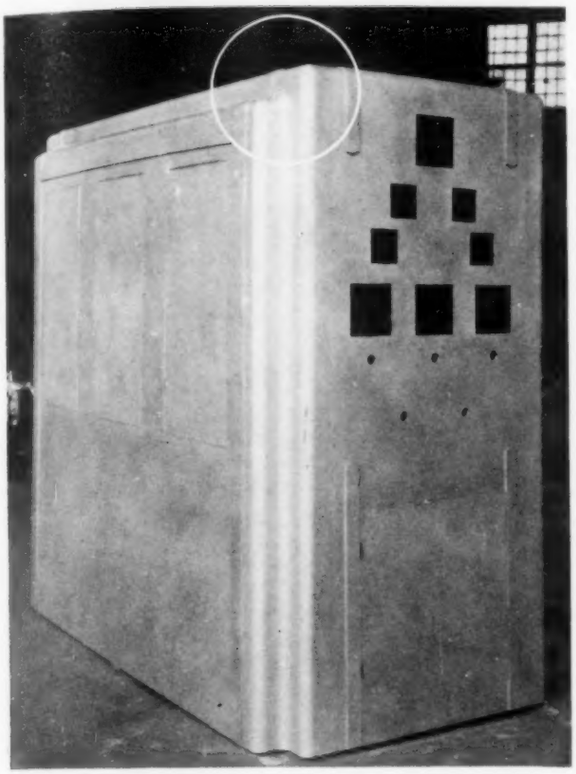


Fig. 2—Cabinet of Welded Construction (Height About 7 Ft.). The Intricate Shape of the Corner Section (Shown in Circle) Necessitated a Steel Casting, Two Views of Which Are Shown in Fig. 3

welding required. The welding trade journals are replete with examples of combination cast and welded fabrications. This clearly indicates the present day resourcefulness of the designer. The early predictions that welding would cause a decrease in the use of steel castings have not materialized. As a matter of fact, we can expect to find a new impetus given to the use of the cast steel product. A recent investigation shows that instead of being regarded as a menace, welding processes are considered as a logical complement to the foundry art. Laws of economics must eventually govern the selection of all industrial materials. A sound merchandising philosophy is gradually developing, based on the realization that every individual metal is a good material, if and when used where it belongs economically.

The engineer of today then, in order to reason logically whether he is to cast or weld, must be conversant with material and labor costs of both methods. At the present time many industrial plants have the facilities to use either method of manufacture. In many cases the final structure is a combination of both.

Such factors as quantity required, delivery, weight reduction, stress concentration, appearance, amount of direct labor involved, amount of machining required, etc., do not necessarily apply to one specific method of manufacture. They may apply equally as well to the casting as to the welding under certain existing conditions.

For example, if one only is required of a certain machine part or piece of equipment, generally speaking, the welded fabrication is favored. If multiple units are required, in many cases the casting is preferred, especially where the design is complicated. Obviously, in quantity production the pattern cost is soon dissipated. For a comparison, see Fig. 1. Granting that plant facilities and burdens vary in different organizations, the general characteristics of the curves as shown still hold good.

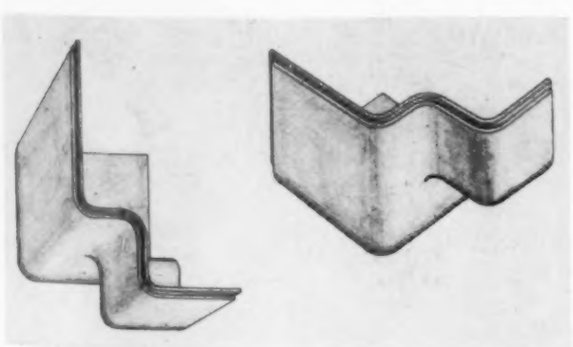


Fig. 3—This Corner Piece Could Have Been Shaped by Pressing, but the Quantity Required Did Not Warrant a Costly Die Charge

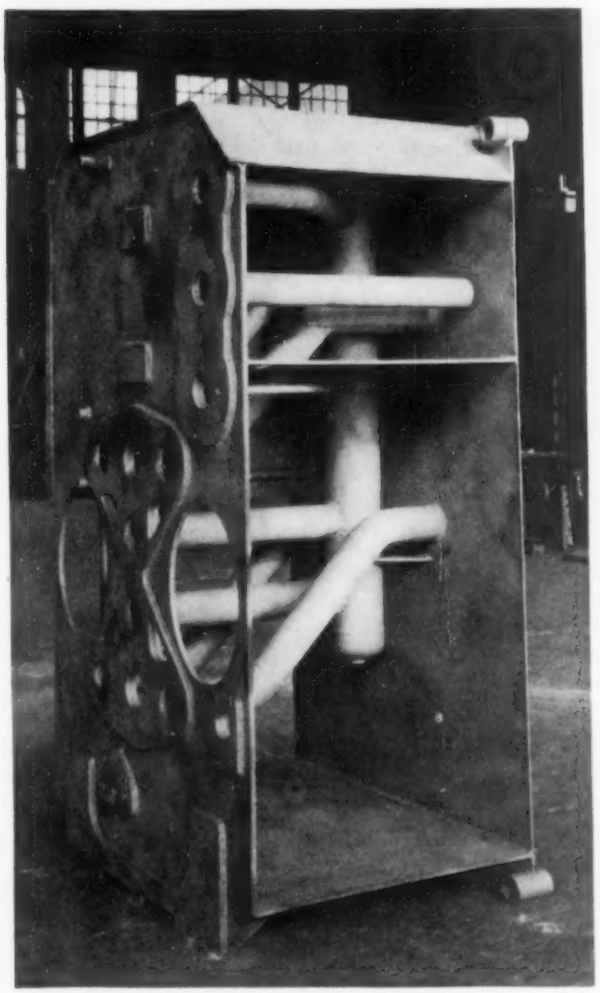


Fig. 4—All-Welded Sump Tank. Think, Tank About 7 Ft. in Maximum Dimensions Was Built with a Tolerance of 1/16 In. on All Sides. The Working Pressure Is 305 Lb. per Sq. In., and It Was Tested at 600 Lb. per Sq. In.

When delivery is a deciding factor and only one or a few pieces are required, usually the welding method is quicker due to the time taken in making the pattern. When many are required and the design does not lend itself to simplification, the casting has an excellent opportunity.

The resultant weight reduction of the welded fabrication over the cast-iron structure does not hold good for cast steel. This is due to the fact that cast steel is equally as strong as the rolled steel used in welded construction. Welding has not only helped to make foundrymen metal-

conscious, but it has caused them to become design-minded. The quality of metal in the steel casting has improved. Furthermore, the design of steel castings now reflects a better placement of the metal.

Welded construction lends itself ideally to the solution of stress concentration. Here again improved design enables the steel casting to hold its own. Castings which are intended to become parts of a combination cast and welded structure receive the proper heat-treatment before any welding is done. The final stress-relieving operation given to a completed structure which contains both steel castings and rolled steel does not materially affect the grain structure in the welding zone.

Little can be said concerning the appearance or eye appeal of a casting as compared to a welded structure. Opinions may vary due to the fact that esthetic ideals are merely a matter of taste.

In considering the amount of direct labor involved especially in the combination structure, we must take into account the quantity required and the intricacy of design. If a large number of individual pieces are required to make a structure and an excessive amount of welding and flame cutting are necessary, a casting should be considered for the more intricate part.

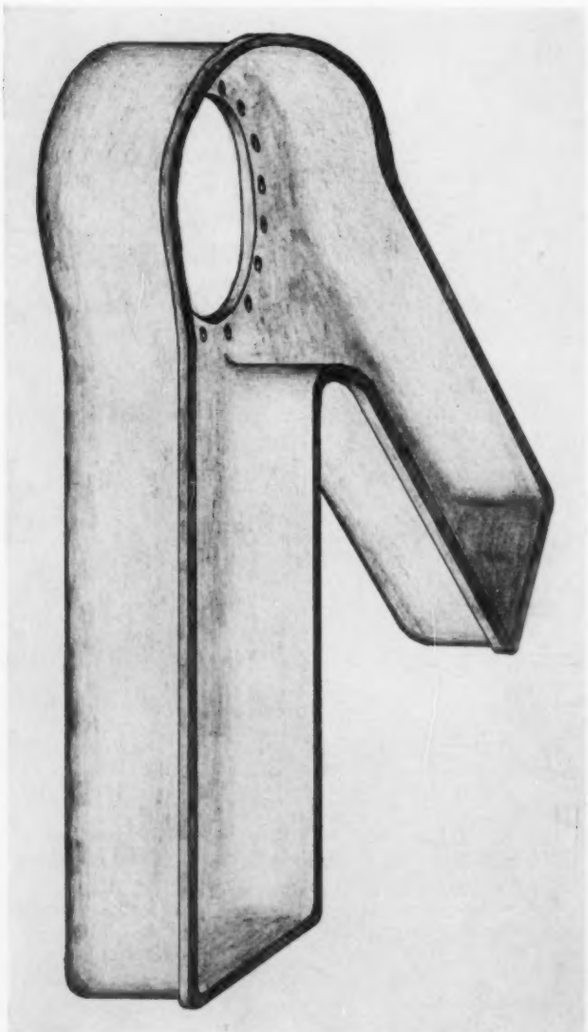


Fig. 5—Cast-Steel Discharge Header. The Discharge Header Is to Be Mounted Under the Top Plate (Shown as a Side Plate in Fig. 4) of the Tank. This Header Could Have Been Made an All-Welded Structure, but a Cost Analysis Based on the Quantity Required Showed the Casting to Be More Economical

Where no special exactness is required, the smooth surfaces of rolled plates can frequently be used without machining. At the present time many steel castings are produced with surfaces that are sufficiently smooth and true to meet the required specifications. In this case neither one has a marked advantage since a close tolerance still demands that they both must be machined.

In view of the fact that many examples of combination cast and welded structures have been shown in recent trade journals, repetition should not be necessary. However, a few examples of combination structures may still be of interest. The cabinet, Fig. 2, is of welded construction. The intricate shape of the corner junction (shown in circle) necessitated a steel casting, Fig. 3. This corner piece could have been shaped by pressing but the quantity required did not warrant a costly die charge. The sump tank, Fig. 4, is also of welded construction. The cast steel discharge header, Fig. 5, was used in conjunction with the piping, and under the top plate of Fig. 4. This piece could have been made a totally welded structure, but a cost analysis based on the quantity required showed the casting to be more economical.

We often hear and see the words—"Casting *vs.* Welding." This statement is rather misleading for they certainly are not opponents. A very definite relationship exists between welding and steel founding. Broadly speaking, these branches of industry are complementary rather than opposed to each other. An up-to-date steel foundry does use welding. Likewise, an up-to-date weldery does use steel castings where castings by virtue of their physical and economical characteristics are the proper thing. The combinations of steel castings, rolled steel and shapes are infinite. It is to the credit of the welding and steel casting industries that so much work has been done successfully. They both are interested in the final results of their joint product. The hearty co-operation given by these groups in the past should insure future progress.

International Silver Plant Is First of New Rigid Frame Saw-Tooth Design

By A. L. LOW†

THIS new type structure, with modern exterior distinguished by continuous horizontal runs of sash, will obtain 100 per cent availability of space from floor to roof by the elimination of all cross members and trusses. Clearance ranging from 14 feet at the top of special "tree-form" columns to 27 feet at the peak of each saw-tooth is obtained by welded roof members which span ten 40-foot production aisles. This will allow for maximum flexibility of operations throughout the plant, which will be devoted to the stamping and buffing of the company's well known flatware lines.

The unusual design, which applies natural tree forms to eliminate all cross members and trusses, facilitates daylighting through the saw-tooth monitors, which face to the north to insure maximum intensity and uniformity of light. Artificial light will be provided by fixtures of the most modern type. They combine mercury vapor tubes

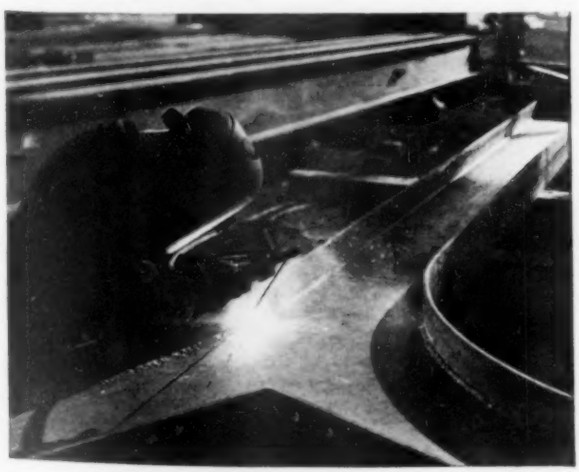
† Vice-President and Chief Engineer, The Austin Company.

The 40-Ft. Aisles, Just Like This One, Will Provide Usable Space from Floor to Roof. Welded Columns Which Branch Out at the Top in Natural Tree Form, Support Right Angle Members Which Bear the Roof Load and Leave the Interior Entirely Without Obstruction to Its Full Height

and Mazda bulbs to maintain 20 foot candles of light throughout the plant.

The roof deck has been constructed of insulated metal to reduce heating costs in the wintertime and to maintain comfortable working temperatures inside throughout the summer. Inasmuch as drop hammers are to be installed throughout the stamping department, special acoustical treatment is being provided over an area of about 8000 sq. ft., to absorb the noise of the hammers and thereby minimize the disturbance resulting from such operations. The floor is being built up on a concrete sub-base 6 inch thick, in which creosoted timbers will be embedded. It will be surfaced with factory maple on a wood base, except in the locker and toilet sections, where monolithic concrete will be used.

Locker rooms and wash rooms have been designed to accommodate at least half of the total body of 400 employees at one time. These facilities have been concentrated in a special two-story section of the plant, 160 feet x 20 feet. The first floor will include women's lockers and toilet facilities, with four large wash fountains at one end, and one of the men's locker rooms with six wash fountains at the other. The entire second floor will be given over to men's locker and wash room facilities.



The Natural "Tree-Form" Columns Which Will Carry the Saw-Tooth Roof in the Rigid Frame Factory

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Can Now Buy Houses, Ready Built, Right at the Factory

By A. F. DAVIS†

NOW you can go to a factory, pick out the size and type house you want, and have it delivered completely built, decorated, ready to move into. The house might even be heated when it arrives!

This is actually what happened recently at Peoria, Illinois. A full size five-room steel house completely built with garage incorporated, was mounted on a large trailer, towed out of the R. G. LeTourneau plant at Peoria to a home site and set down on the lot by a tractor. A few hours later, connections were made for water, gas and electricity; the drapes were up; the floors carpeted; each room was apropriately furnished and the house was ready for occupancy.

This house, shown in the accompanying illustration is undoubtedly the first house to be completely built inside a factory ready for occupancy.

In constructing this house, full advantage was taken of modern methods of steel construction. The steel was joined together by the shielded arc process of arc welding.

Ready Built House

Under special permit, a dwelling of this type can travel the highways for any distance, readily moving 100 or 200 miles overnight to be in place next morning ready for occupancy as soon as connections are made for water, gas and electricity.

The all steel house here described, and illustrated, was developed to provide a complete attractive home to rent, or sell, at moderate cost. This all steel house is fireproof, dust-proof, termite-proof and practically airproof. In addition, it should prove almost earthquake-proof and will be little, if any, affected by settling or shifting of the ground on which it stands. With proper care and repainting when needed, the house should last indefinitely.

† Secretary, The James F. Lincoln Arc Welding Foundation.

Welding and Annealing the Telescope Parts*

By NORMAN L. MOCHEL†

THE decision to employ arc welding so extensively in the construction of the tube and mounting of the 200-inch telescope for Mount Palomar is another outstanding example of the confidence in the welding art that has been developed in the minds of engineers in many fields of activity. Progress in the welding art has been rapid and quite amazing. The past few years have seen a widespread adoption of welding in important engineering construction, often in the place of older and well-established methods of manufacture.

There is nothing of an experimental nature in the adoption of welded construction for the various members of the telescope. Other structures of comparable size and complexity, and of like value and importance, have been successfully produced by this method.

In the case of the telescope, steel plates, bars, structural shapes and a few steel forgings have been welded together to form the member parts. The size and shape of these member parts naturally reflect the general design, but have also been influenced by such practical considerations as the availability of material, machining facilities, transportation and the necessity for minimizing internal stresses and resulting distortions.

It must be understood that the various member parts are prepared by machining for bolting together at Mount Palomar. Frequent references to all-welded construction may have given the erroneous impression that member parts were to be joined on location by welding. The writer has encountered this impression with many persons who inquired of the matter. It is true that in many large engineering structures, member parts have been and are being joined by welding on location. However, in such cases, invariably the construction and intended service are such as to tolerate distortions that would take place during welding or during the useful life of the apparatus, or in which the presence of variable and unknown degrees of internal stress are of little concern. Obviously such conditions could not be tolerated in the construction now under discussion.

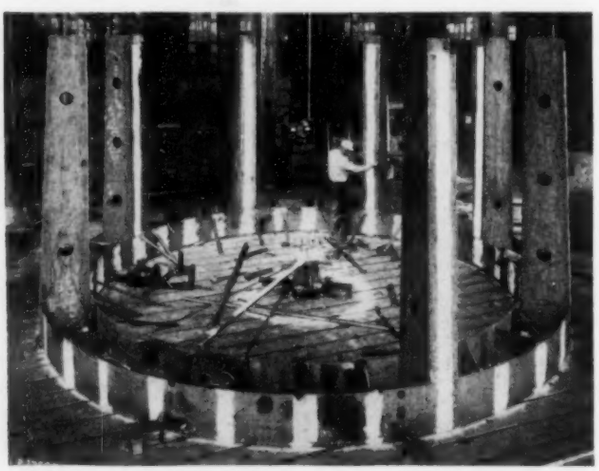


Fig. 1—Fabrication of the Bottom Ring and Uprights of the Prime Focus Cage

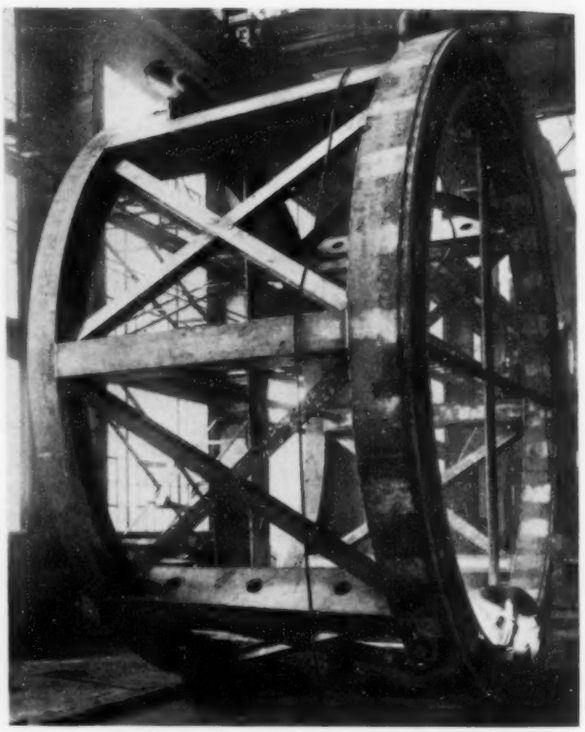


Fig. 2—Fabrication of Prime Focus Cage Nearing Completion

Materials

In any discussion of welding, one is naturally interested in the materials that are to be used, and that must submit to welding. Again one encounters an erroneous impression, that a telescope must be constructed largely of special alloys that have low expansivity. While it is true that some materials of this type are used in connection with the mirror and other optical parts, most of the material used for the tube and mounting is quite ordinary mild carbon steel.

All of the materials that are being welded are of standard commercial grades that are being welded day in and day out at the South Philadelphia Works. This is an important practical consideration.

In all cases, plates, bars and structural shapes have been rolled by one supplier from specially selected heats, to give the greatest possible uniformity of composition. Plates less than $1^1/_2$ inches thick were made of the usual flange quality of steel plate, similar to that covered by A. S. T. M. Specification A-70. All such steel for the tube was made from a single heat, specially melted for the purpose. Plates $1^1/_2$ inches thick and greater were rolled from silicon-killed steel poured into hot-top ingots, to guarantee soundness of section. This steel is similar to grade "*A*," A. S. T. M. Specification A-150. Two carbon-molybdenum steel forgings are used in building up the declination bearing housing.

* Presented at January 22nd Meeting, Boston Section, AMERICAN WELDING SOCIETY.

† Metallurgical Engineer, Westinghouse Electric & Mfg. Company, South Philadelphia Works.

Fig. 3—One of the East and West Panels of the Tube, with Welding Practically Completed

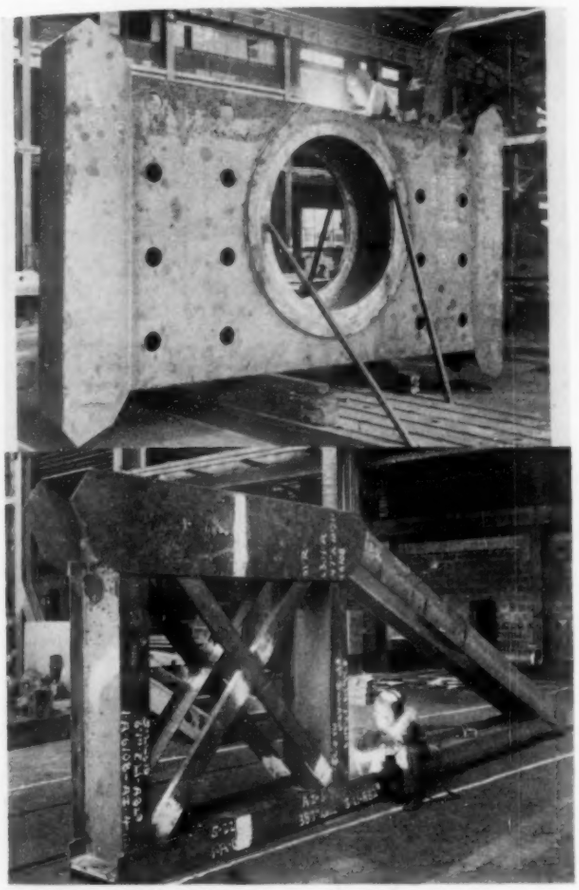


Fig. 4—Portion of South Panel of the Tube, with Welding Practically Completed

The uniformity of composition of the steel used in the tube and "horse-shoe" is shown in the following table:

	C	Mn	P	S	Si
Material for Tube					
Plates under $1^1/_2$ in. thick	0.10	0.40	0.016	0.034	0.16
Plates $1^1/_2$ in. thick and over	0.24	0.50	0.009	0.023	0.25
Bars	0.09	0.39	0.016	0.025	0.18
	0.09	0.38	0.016	0.030	0.05
	0.09	0.40	0.016	0.043	0.03
	0.09	0.40	0.016	0.035	0.05
	0.16	0.45	0.015	0.036	0.08
	0.12	0.40	0.010	0.030	0.04
Structural Shapes	0.10	0.40	0.011	0.036	0.12
Material for "Horse-Shoe"					
$4^1/_2$-in. and 4-in. plates for main part (inner and outer bands)	0.22	0.50	0.031	0.028	0.22
	0.24	0.44	0.016	0.027	0.19
Plates $1^1/_2$ in. thick and over	0.23	0.56	0.015	0.032	0.26
	0.24	0.53	0.014	0.029	0.25
	0.24	0.47	0.016	0.031	0.25
	0.24	0.47	0.018	0.023	0.27
	0.27	0.54	0.015	0.027	0.26
	0.25	0.48	0.011	0.022	0.27
Plates under $1^1/_2$ in. thick	0.11	0.42	0.013	0.023	0.16
	0.10	0.42	0.011	0.028	0.16
	0.12	0.32	0.016	0.020	0.16
	0.10	0.43	0.013	0.025	0.16

It is interesting, in connection with the materials used, to note that each outer band for the three sections of the "horse-shoe" required a piece of plate $4^1/_2$ in. thick by 60 in. wide by 47 ft. long. These pieces were accurately formed to desired curvature under the 12,000-ton forging press at Bethlehem.

Electrodes

Arc welding only has been employed and, in all cases, heavily coated electrodes of the mineral-coating or slag-producing type were used. These were of but two makes; both of the highest quality available.

It is well recognized today that electrodes can be devised that will best meet some given condition of deposition. Full advantage of this has been taken and three kinds of electrodes, as regards position of deposition, have been used. One was used for all down-hand butt welds; another for all down-hand or horizontal fillet welds; and yet another for welds that of necessity had to be made in a vertical position. Overhead welding has been avoided.

Operators

In our regular work at South Philadelphia, we are called upon to qualify our welders to a variety of codes and specifications. For example, we have had construction under way on our floors at practically the same time requiring that we meet the A. S. M. E. Boiler Code for Unfired Pressure Vessels, and A. P. I.–A. S. M. E. Code for Unfired Pressure Vessels for the Petroleum Industries, the U. S. Navy, the Bureau of Steamboat Inspection, the American Bureau of Shipping, the Pressure Piping Code and the requirements of two well known insurance companies. Of necessity, we have developed all-inclusive codes and process specifications of our own, so that qualification under our own more extensive requirements qualifies an operator to perform under any of the above codes and specifications.

Operators performing welding on the telescope tube and mounting have qualified under the outlined system, and are welders of the highest type.

Fig. 5—Early Stage in the Fabrication of One Section of the Yoke Horse Shoe

Welding Apparatus

The electrodes used in this welding are of such nature that they behave equally well with D.C. or A.C. welding apparatus. Both D.C. and A.C. units are available at South Philadelphia and both have been used throughout. The A.C. welding was found to be especially useful for welding into corners.

Welding

All welding on the tube parts and to date on the "horse-shoe" has been manual welding. The two declination bearing housings were produced using automatic welding for the longitudinal and external circumferential welds.

In welding such large parts as those being described, careful study and planning of the work is very important. There is a best place to start, and a best sequence of operations. One does not have an opportunity to practice with a first few, and thus develop a final technique. There are no trial pieces to be thrown away. In the case of some parts, there is but one piece of a kind to make; in others, there are two like pieces.

For welding such large structures as those under discussion, large leveled floor plates are of absolute necessity. The need for ample space, for proper supporting and of firm foundation will be obvious from an examination of a number of the illustrations accompanying this article.

The welding of the tube parts and the progress to date on the first "horse-shoe" section can probably best be described by the use of a few photographs showing the several parts, and supplemented by a few comments in passing.

The general design of the telescope has been described elsewhere, and no attempt along such lines will be made in this article.

Figure 1 shows a stage in the fabrication of the prime focus cage. The lower main ring of the cage was formed on the floor plate and the uprights, formed elsewhere as detail parts, assembled as shown. The ring is approximately 22 feet in outside diameter and the cage is roughly 12 feet long with the top ring in place. The gage for controlling the proper radius and for accurately locating the pieces of tubing that are in evidence, will be noted. The simple method for supporting and clamping the ring both inside and out shown. The welding art has certain advantages over other methods of fabrication when it comes to supporting and clamping down, as clamping blocks, struts, stays, etc., can always be attached exactly where wanted by welding. They are readily removed later. The use of intermittent welding will be noted in most of the parts.

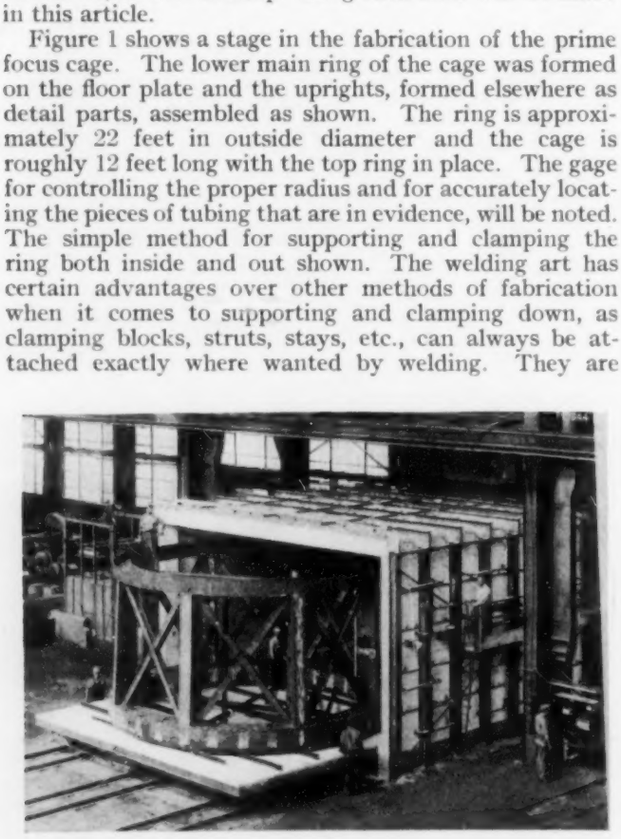


Fig. 6—Prime Focus Cage Being Moved Into the Annealing Furnace. Size of Furnace: 26 Feet Square and 20 Feet High

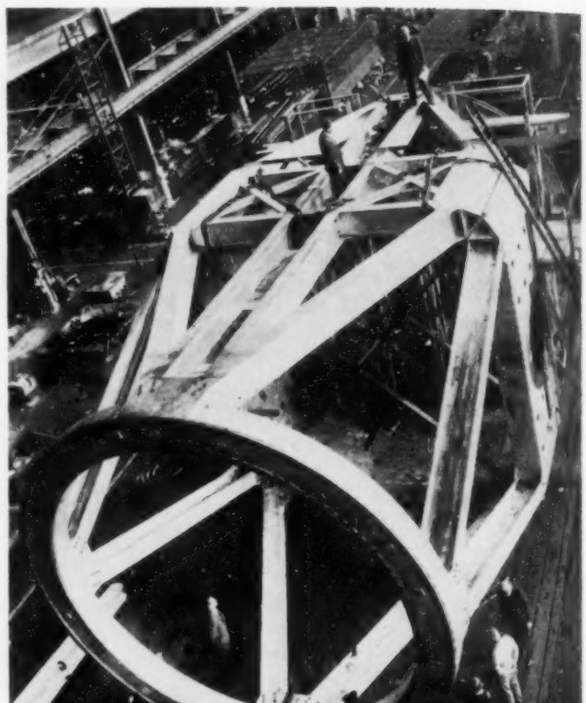


Fig. 7—Completed Tube Which Will Carry 200-Inch Mirror in World's Largest Telescope

In Fig. 2 the prime focus cage is nearing completion, so far as welding is concerned. The forming of the "X" members from "I" beams will be noted, the method of joining by welding being plainly shown. Crossed tubular supporting members at each ring have been welded in place to securely hold the rings in shape during handling to and from the annealing furnace, and during annealing.

One of the east and west panels when welding is practically completed is seen in Fig. 3. A portion of the south panel is shown in Fig. 4. These illustrations more or less speak for themselves and need no comment.

Figure 5 shows early stages in the fabrication of one of the end sections of the "horse-shoe." This "horse-shoe" has an outside diameter of approximately 46 feet. Reference has already been made to the size of plate used to form the outer band. The one side plate was first formed. There are two circular lines of welding in the side plate (or bottom plate in the position shown). This is a ring 10 feet in diameter and $3^1/_2$ inches thick, to which the 10-foot diameter yoke tubes of the telescope will bolt. The ring has been welded into the 1-inch thick plate, flush on the inside as shown. The side plate was clamped down and the inner and outer bands moved into position as shown, and clamped as shown in Fig. 5, around the outside. Clamping blocks were welded to the bands as shown. The internal plates, reinforcing members, etc., were fitted in place and secured by tack welding. After properly fitting the cellular or box-like structures that fasten to the outer band and fixing the various component parts by welding a bar across them, they were removed from the main part and welded under the most ideal conditions on the floor. This had a double advantage. It permitted turning them in any position to

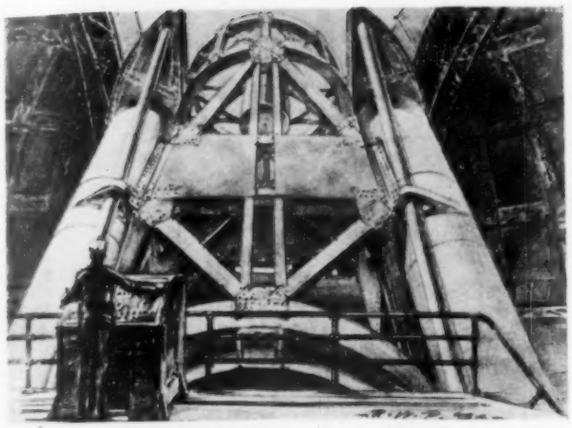


Fig. 8—A "Preview" of the Telescope with an Operator at the Control Stand

get the best welding, and it avoided setting up undue heating and stressing of the main members by the considerable amount of welding necessary. There were five of these sub-assemblies; two are shown in place in Fig. 5 and spaces for the other three may be readily appreciated. While this was under way, welding was carried out on the larger reinforcing members. Welding was started at the center and worked outward. At the time shown, the welding of these members was practically completed. The five sub-assemblies were then moved back into position and welded in place.

The work on this part is now in progress. The further steps have been carefully planned and no trouble is anticipated. There will be two stress-relieving treatments applied, one before the other side plate is installed and one upon the fully completed structure.

Annealing or Stress-Relieving

All of the telescope parts have been carefully annealed to relieve internal stresses. It is standard recognized practice to stress-relieve welded mild carbon steel structures by heating slowly in a suitably constructed furnace to a temperature of 1100/1200 F., holding for a period of time proportioned on the basis of at least one hour per inch of thickness and then cooling slowly in the furnace.

In order to thoroughly stress-relieve the telescope parts, we have used a double annealing cycle, heating to 1150/1200 F. holding for a period of three hours for the first one inch of thickness plus an additional hour for each additional one inch thickness or fraction thereof, followed by a slow cooling in the furnace until the temperature has fallen below 600 F.; and then repeating this cycle in its entirety and cooling below 300 F. before the furnace doors are opened.

Figure 6 shows the prime focus cage being moved into the annealing furnace. The furnace shown was especially constructed to anneal the telescope parts. The work rests on a car type bottom for ease of operation. A special type of gas burner was used that gives a quieter acting flame and avoids long hot flames impinging upon the work. Burners are also located in the truck or car at the front of the furnace to avoid a "cold" spot at the front. The door or front cover of the furnace is made in sections that hang from the roof and tightly seal the furnace. Baffles of heat insulating bricks were built up at four points where the circumference of the cage came too close to the walls and the burners to prevent undue or rapid heating at those points. Thermocouples were in actual contact with the work and continuous autographic records were made from four thermocouple locations throughout all annealing periods.

The following summarizes the treatment of the prime focus cage, as an example:

12 hours heating to 1160 F.
6 hours holding at 1150/1160 F.
11 hours cooling to 600 F.
10 hours reheating to 1150 F.
$6\frac{1}{2}$ hours holding at 1150/1160 F.
42 hours cooling to 125 F.

Reference was made earlier, in commenting on Fig. 2, to the crossed tubular supporting members at each end. If one closely examines Fig. 6, it will be noted that additional tubular members were placed in an upright position between the crossed members to prevent their sagging and possibly distorting the ring sections during annealing. Also, blocks were placed on the car floor underneath the lower crossed members to prevent their sagging. Supporting of support members is just one item of the care that must be used in such work.

Results—Accuracy of Work

One is naturally interested in the results of the welding, how closely were the parts held to size throughout welding and annealing. Four indications will be cited.

When the prime focus cage was placed on the boring mill to face the lower end where it bolts to the top ring of the tube, the departure from roundness was not greater than $\frac{1}{16}$ inch.

When the top ring of the tube was placed on the mill to face the upper end, which takes the prime focus cage, the departure from roundness was of the order of $\frac{3}{32}$ inch.

Figure 7 shows the completed tube. The bolted joint of the two panel sections will be noted. These two flanges were not machined on the edge or outside surface, yet at no place in four such joints was there more than $\frac{3}{16}$ inch difference between two mating flanges along these outside unmachined surfaces. In general, the joints were much closer than this figure. The joint faces were, of course, machined to a definite fit. There was very little difference in thickness of the mating flanges.

When the top ring was lowered into place the four gussets that hold to the "A" frames were found to be accurate as to position within approximately $\frac{1}{16}$ inch.

Cleaning and Painting

All parts are carefully cleaned prior to painting by sand blasting. A priming coat of aluminum paste in varnish is first applied. This has been considered more desirable than a red or blue lead or a red oxide primer, so that as scratching occurs in handling or later in service, the objectionable appearance of blue or red streaks will not be in evidence. A high grade egg-shell synthetic resin enamel of light gray color will be used for the second coating and will give a pleasing appearance (Fig. 8).

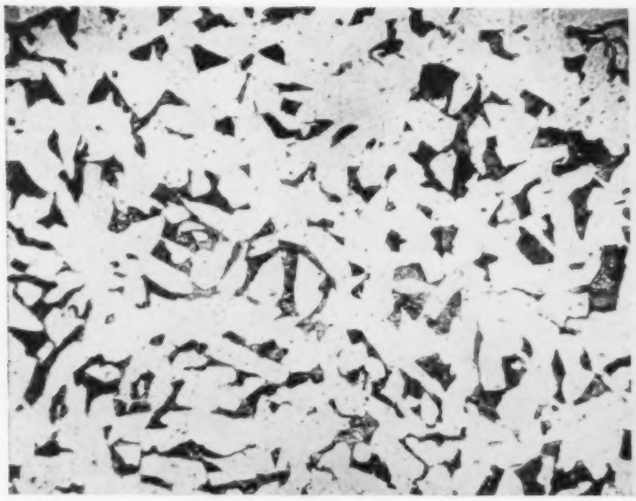


Fig. 1—Mag. 200 X Plate 0.27% C

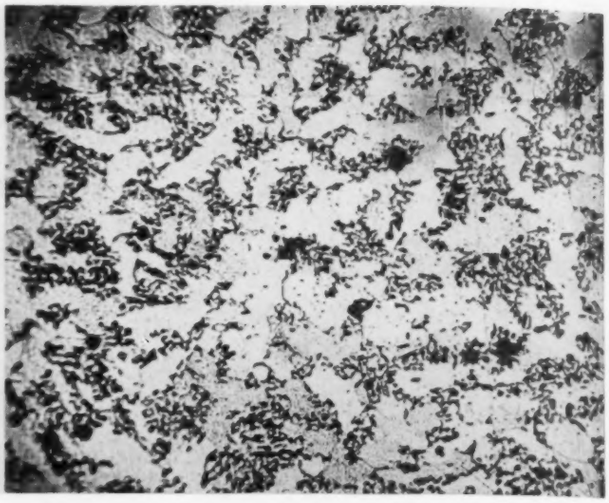


Fig. 2—Mag. 200 X. Affected Zone in Plate Adjacent to Normal Structure Showing Crystallized Pearlite

Why Welding Procedure Control?

By C. LOUIS*

IN THE course of welding seven metallurgical changes take place in the parent metal due to heat penetration into the plate by the terrific heat developed in the arc.

The higher the strength of the plate and the more complex its chemical structure, the greater becomes the possibility that these changes may be injurious.

The amperage used and the length of the arc influence the amount of heat evolved and the extent of its penetration into the parent metal.

Poor fit-up may cause excessive heating, and, therefore, undue distortion. Too high an arc current, or poor technique may cause undercutting and slag inclusions. So, we could go on and list numerous causes of weld failure.

From a standpoint of good engineering it is desirable to be able to predict whether or not a weld will stand up in service, and how much welding is necessary to produce the required result.

Good welding procedure aims to correct any detrimental factors introduced in the cause of welding so that the finished joint shall be as good, or better than the original plate. Therefore, welding procedure control.....

One step in the control of the operator's technique is the periodical welding of test plates.

Our present article will attempt to describe one cause of weld failure due to incorrect application of the finished bead.

* Research Engineer, The Champion Rivet Company.

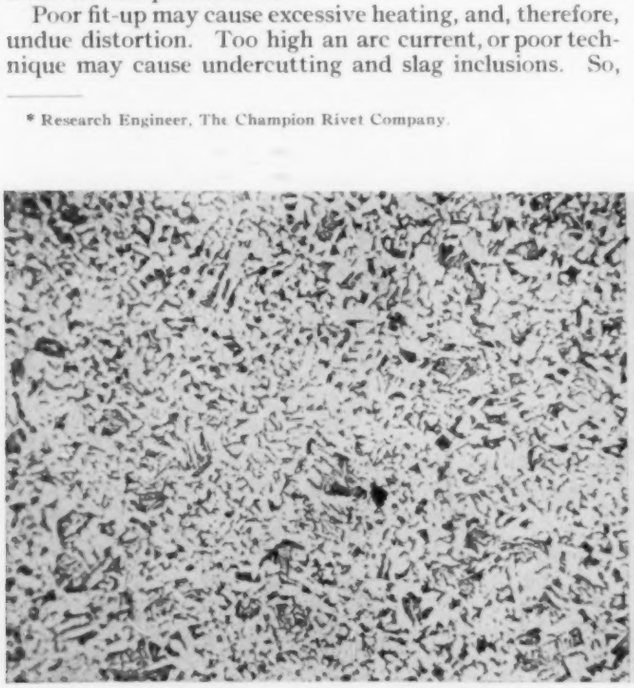


Fig. 3—Mag. 200 X. Affected Zone in Plate Adjacent to Weld Showing Entire Structure Recrystallized and Refined

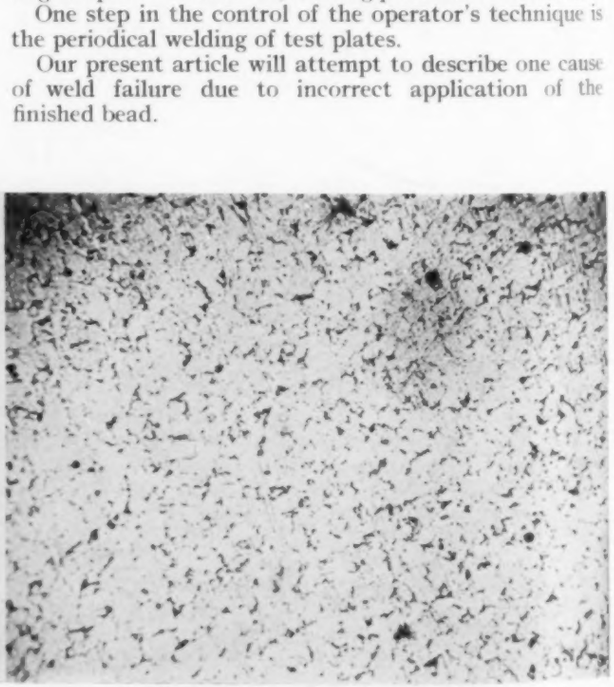


Fig. 4—Mag. 200 X. Normal Structure of Weld Metal

Fig. 5—Mag. 200 X. Affected Zone in Plate Adjacent to Finishing Bead Which Overlapped Plate 3/8 Inch Showing Dispersed Troostite

Fig. 6. Mag. 200 X. Dendritic Structure in Finishing Bead

Figure 1 is the normal structure of a 0.27 C plate as received from the mill. Mag. 200 X.

Figure 2 is the structure of the affected zone Mag. 200 X adjacent to the normal structure, the depth of this zone varies with the size of electrode and the heat used. Using 5/32-inch rod at 160 A gives a zone about 0.1 inch deep.

Figure 3 is the structure of the affected zone adjacent to the weld. Depth of this zone is the same as in Fig. 2. Sufficient heat has penetrated in this zone to cause complete recrystallization of the normal plate structure. Mag. 200 X.

Figure 4 is the normal structure of the weld metal Mag. 200 X.

Figure 5 shows the abnormal structure adjacent to the finishing bead which overlapped the plate about 3/8 inch. This is dispersed troostite. Troostite is relatively hard and brittle, and in many instances this condition caused the premature failure of the free-bend specimens when welding 0.25 C plate, or higher.

Figure 6 shows the dendritic stucture encountered in the finishing bead. Mag. 200 X. This type of metal is undesirable being much coarser and more brittle than the normal weld metal.

How can you correct this trouble?

In the first place, confine the finishing beads to the edge of the groove as much as possible and don't overlap the plate more than 1/8 inch.

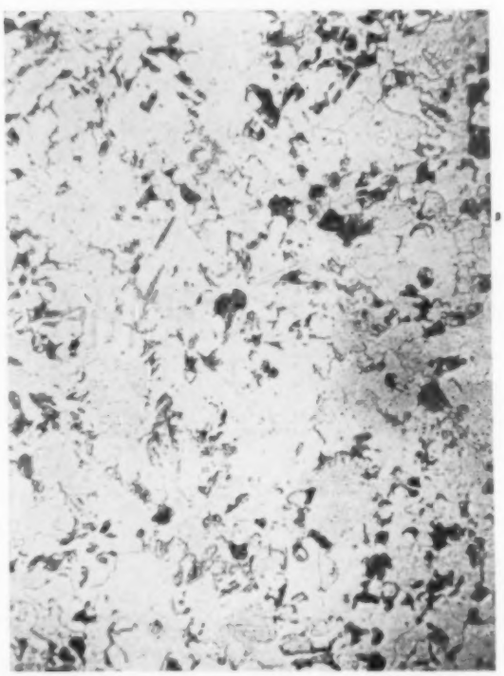
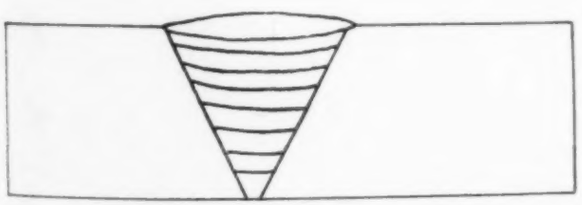


Fig. 9—Mag. 200 X. Affected Zone Adjacent to Finishing Bead After Heat Treatment @ 1450° F.—Cooled with the Furnace



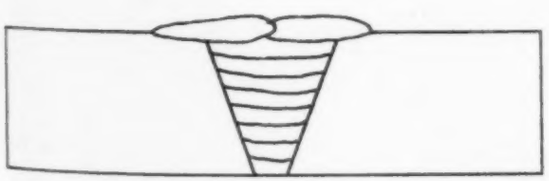


Fig. 7—Correct Finishing Bead

Fig. 8—Incorrect Finishing Bead

Secondly, where possible, build up the finishing bead sufficiently so that in subsequent machining this coarse structure will be eliminated.

Furthermore, the heat from the last bead penetrating into the plate will cause, in all probability, the structure encountered in Fig. 5 to change into the structure shown in Fig. 2 which, being spheroidized, has greater ductility and strength than the normal structure shown in Fig. 1, and is, therefore, desirable.

Figs. 7 and 8 show graphically the correct and the incorrect method of finishing.

If it is not possible to machine the weld and yet necessary to eliminate this bad condition, a stress relieve at 1450° F. is necessary.

This heat treatment will change the troostitic stucture into that shown in Fig. 9.

This does not imply that all single pass welding has an inherent weakness. Although this condition occurs in all single bead work the effect of this structure upon the physical structure of steel, the carbon of which is below 0.25%, is negligible and need not cause any concern.

The author has been unable to find any technical data relating to this condition, and, therefore, invites comment and constructive criticism.

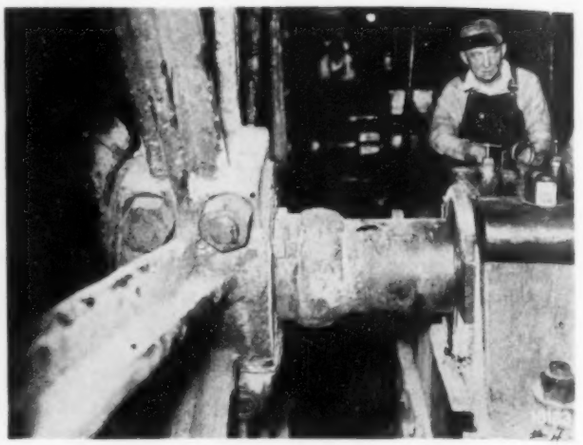
Thermit Repair Again Restores Cable Car Service in Rapid Time

By MERRITT L. SMITH†

TO provide satisfactory surface transportation over the steep hills north of Market Street in San Francisco, the Market Street Railway operates a cable car system. Five cable lines are driven from a central power plant in which propulsion cables are wound on sheaves mounted on two large shafts. The shafts are driven through herring-bone gears having a diameter of 14 feet and a face of 24 inches. The shafts are 18½ feet long and approximately 12 inches in diameter. Each assembly weighs 52,000 pounds.

About two years ago a break in one of the shafts paralyzed the entire cable system but, by means of Thermit welding, an emergency repair was made and operation was restored after a shut-down of only thirty-seven hours.

The Thermit Weld in the Making



Completed Weld

Recently this same shaft failed again on the opposite side of the gear, several feet from the previous weld. The shaft was in operation for some time before the break was discovered and during this time the first weld carried the weight of the gear as well as the operating load. Ample proof of the strength and soundness of the original weld was thus provided. As in the first instance, the break was so located that a Thermit repair could be made without dismantling the shaft, and, although, a new shaft was available, a four-day shut-down would have been required to install it, so that to save time Thermit welding was again decided upon.

Starting work at two o'clock in the morning, the welding crew, under the supervision of F. N. Keithley of the Metal & Thermit Corporation, set-up the mold box, prepared the mold, preheated the shaft for six hours and poured the weld by noon of the same day. After allowing another six hours for the shaft to cool, the mold was stripped away and the gates and risers were removed in ample time to permit replacement of cables and the resumption of operation at the usual five o'clock hour the following morning. Actual working time was four hours less than on the previous occasion, which had been considered something of a record. Two crucibles were employed in making the weld and 250 pounds of Forging Thermit were used.

The repair was made under the direction of Mr. W. D. Chamberlain, Superintendent of Maintenance of the Market Street Railway Co.

† Advertising Manager, Metal & Thermit Corp.

Fabrication of Machine Parts by Welding*

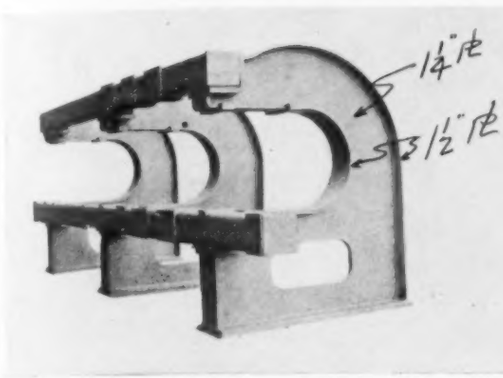
By T. JOHNSTON†

THE practice of using rolled steel in the fabrication of machine bases and parts has come very much to the fore in the last few years. Not many years ago very few machinery manufacturers even thought of using welded steel, but now the biggest percentage of all these manufacturers automatically ask themselves when designing a new job, "Does this Machine lend itself to Welded Rolled Steel construction?" and often when the design does not lend itself to the use of steel to the best advantage, the design is changed to permit use of many of steel's known benefits.

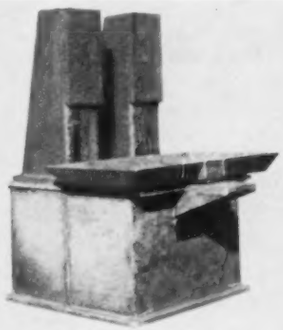
For such a radical change to have been brought about in so short a time in as old a profession as machinery building, the advantages must be manifold; for there is no one so jealous of his reputation as a machinery manufacturer and some of them enjoy among the highest reputations in the land.

We have mentioned that there are advantages in using welded rolled steel and it might be well to enumerate

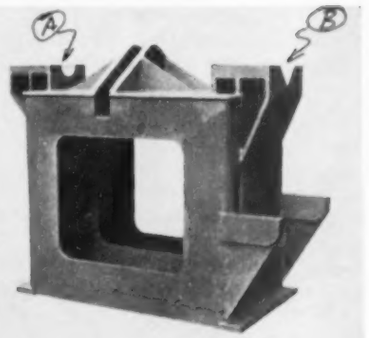
* Read April 20, 1937 at Lincoln Electric Company, Intensive Course of Arc Welding, in Pittsburgh.
† Whitehead & Kales Company.



A Typical Example of What Can Be Done with a Flame Cutting Machine in Conjunction with Arc Welding



A base, 2 Columns and a Chip Pan for a Drilling Machine. Note Rounded Corners



Note Rounded Corners on This Machine and the Fact That Blocks A and B Were Rough Machined Before Assembly, Leaving Stock for Finished Machining Later

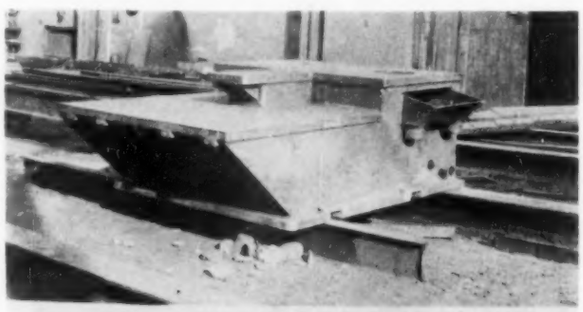
them at this time before going into the procedure of fabricating a welded steel machine part.

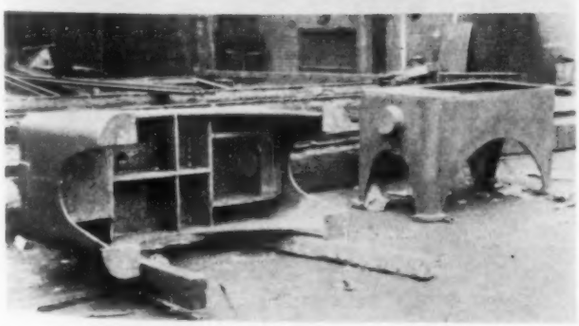
In a paper of this kind one does not wish to appear to criticize a competing product, but because cast iron has been for years an accepted and known metal in the trade and to bring out rolled steel's advantages I know you will allow me to compare the two materials. In the writer's opinion, steel cannot altogether replace cast iron, but there are places where rolled steel is a decidedly better medium.

In a welded steel machine part the material most commonly used is standard hot rolled steel with a carbon content of 15 to 25. This steel is more rigid than ordinary cast iron, cast iron failing at 20,000 lb. and steel yielding at 40,000 lb.

Steel is of particular advantage when the part is to be in tension as steel will withstand approximately seven times greater tensile stress than cast iron.

Rigidity is one of the most essential features of machine construction, and as can be seen from the foregoing paragraphs steel is a very rigid metal.





(Top) Two Head Drilling Machine That Had to Be Machined to $\pm \frac{1}{10,000}$ of an Inch

(Bottom) Machines for Burnishing Gears for Making "Silent Seconds" in Automobiles. The Original Base Was Made for Less Than Patterns and Cores Would Have Cost

With modern flame cutting and welding equipment it is often possible to make delivery of the completed part before the patterns and cores could have been made if the casting method were used. More prompt delivery and the savings of both pattern costs and pattern storage charges are definite advantages.

One benefit in using welded steel is the fact that changes may be made at any time, even if changes are required after the machine is complete. This is a simple operation when welded rolled steel is used. All that is needed to make changes is a blow torch, a welding machine and a skilled operator, but you can all readily see the expense and delays involved when some other method is used.

A rolled metal is the most uniform metal obtainable, free from hard spots, blow-holes and sand pockets. This consequently permits of easier and more rapidly machining.

The greater strength and rigidity of rolled steel allows a saving in weight to be effected. Members do not have to be arbitrarily thickened to allow metal to flow, the designer specifying just enough metal to do the job.

So far we have been mainly concerned with the metal we propose welding together to form our machine part. Let us now summarize the advantages of rolled steel and then consider the welding procedure and methods. The advantages of rolled steel are: greater strength, great rigidity, lower cost, quicker delivery, lighter weight, a more uniform metal, the ability to make changes and additions cheaply at any time and no patterns to make and store.

Rolled steel we have had with us for many years, but welding is the method that has made the advantages of steel available to machinery manufacturers, and we must give all credit to welding for it has never let us down.

To make a satisfactory product that is acceptable to reputable manufacturers one must have first class equipment, skilled engineers and competent workmen. In machine construction slip-shod methods cannot be tolerated.

There are many rolled shapes on the market and the alert designer, once has decided the part under discussion is to be of rolled steel construction, will consider all the shapes available and take full advantage of these standard rolled shapes. The bulk of the machine bases, however, will be made using flat plates, burned to shape and bent as required. This way an endless variety of conditions can be successfully met.

The first stage in the shop is laying out the job in the Templet Shop and making full size templets to which the steel will be cut.

The cutting of the steel is naturally the next step. Here I think we should pause and say a word in praise of

modern flame cutting equipment, which can be used with a mixture of acetylene and oxygen, city gas and oxygen or other gases; and controlled so accurately with modern machines that a very smooth cut is the result, held very accurately to dimension. On a lot of jobs the writer is acquainted with, the burned edge was so smooth, square and accurate that no machine shop work was necessary. It is sufficient to say that with up-to-date flame cutting equipment we can now burn steel to the required shape with square and smooth edges and hold the size to a very close tolerance.

After the steel has been cut to the required shape those parts that need forming are next bent. There are many bending devices on the market and most of them are used in rolled steel construction including the leaf brake, press brake, hydraulic press, crank press, bull dozers, etc.

The next stage is to assemble the parts together which is done on well aligned surface plates. A level rigid base to work on is absolutely essential. The work is here assembled, tack welded together and parts inaccessible after full assembly are also completely welded. The tank welds must be of sufficient strength to hold the component parts securely in place for the final welding.

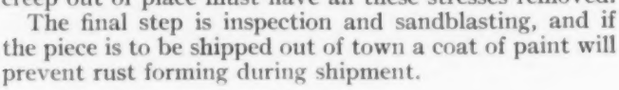
After everything has been fitted, checked and well tacked together, the piece should be placed on a welding manipulator or positioner and welded up completely. This gives the welder an opportunity to turn the piece to the best advantage to weld by the down hand method.

When the piece is completely welded it should be braced in any portion that might distort under heat and placed in the annealing oven to be normalized. This is a very necessary step as stresses are set-up in the steel due to rolling and welding puts more stresses there; and any first class job that has to "stay put" and not creep out of place must have all these stresses removed.

The final step is inspection and sandblasting, and if the piece is to be shipped out of town a coat of paint will prevent rust forming during shipment.

Practical Hints on Using Rolled Steel for Machine Bases

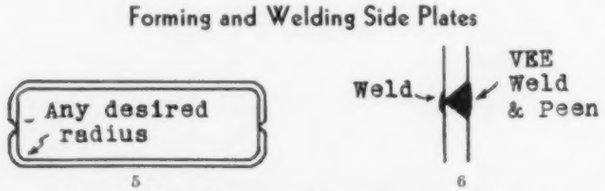
Welding Top to Sides



1 2 3 4

Fig. (1) is not as satisfactory as fig. (2) because of the expense of veeing, and also there is the exposed weld on a smooth surface. Fig (2) puts the weld out of sight, gives the welder an ideal place to weld, and saves the expense of veeing. However, sometimes it is desired to have the plates flush as shown in fig. (1). In this case vee both plates at 45° as shown in fig. (4) and not only one plate shown in fig. (3). The reason for this is that the welder has difficulty in fusing his arc into the root of the vee when he has only 45° to work in, whereas with 90° to work in he can get proper fusion right to the bottom of the vee.

Forming and Welding Side Plates



5 6

For the sake of appearance side plates are usually bent at the corners as shown in fig. (5). Fig. (6) shows how the vertical joints are welded. These can be ground flush after welding.

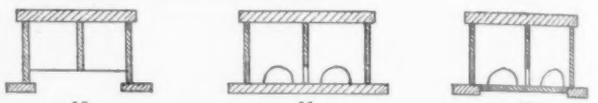
Welding Feet On

7 8 9

Usually we run a bar all around the structure as shown in Fig. (7), (8) and (9). Fig. (7) is a very poor way of welding this bar on. Fig. (8) is used where there can be no projection into the structure. Fig. (9) is the best method, the advantages are direct load on the feet, the welder can get at the pieces easily to weld, and no veeing is necessary.

Ribbing or Reinforcing

It is very essential that a machine base be well ribbed. Apart from the rigidity which is obviously of prime importance, there is the acoustics to be considered. An unribbed hollow base is a beautiful sounding box magnifying sounds greatly. Correct reinforcing eliminates this trouble.



10 11 12

Fig. (10) shows a section through a completed base showing the best way to assemble the various parts.

Figs. (11) and (12) show the same construction but with the difference that the base is required to be watertight.

Normalizing

Correct stress-relieving is of the utmost importance in using rolled steel. There are stresses in the steel that are put there by the rolling, then again the welding puts more stresses in the structure. Peening the welds helps the welds and may relieve some local stress in the welds, but can have no effect on the stresses in the whole structure. The only practical way to eliminate these stresses is to normalize the piece by heat and let the piece cool slowly without opening the oven.

Aluminum Chairs

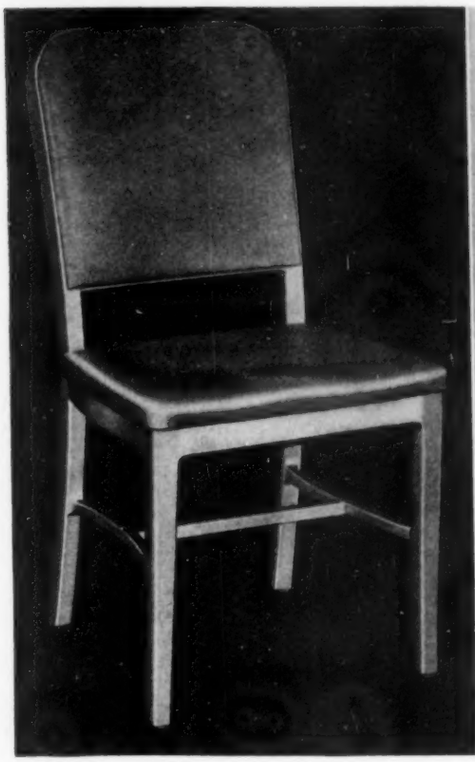
By OWEN C. JONES†

Welded Construction Assures Strength, Beauty and Freedom from Maintenance

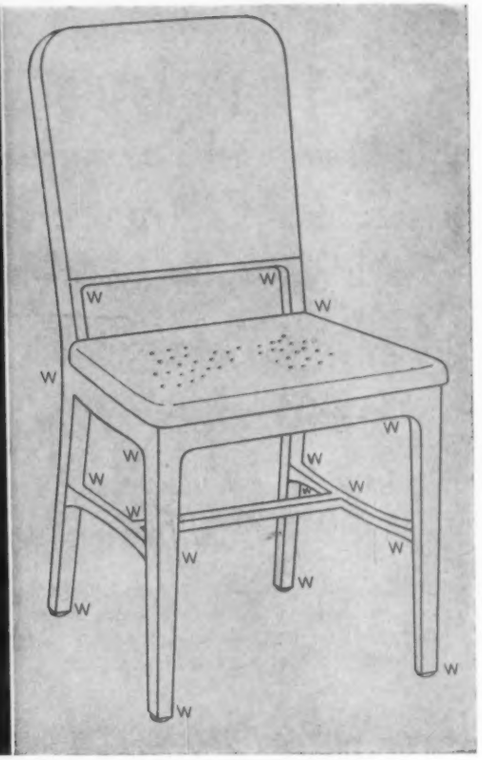
BECAUSE of its many advantages, welded construction is widely used for the fabrication of metal furniture for both household and office. The welded joint assures full strength and complete freedom from maintenance, as there is nothing to work loose, even with constant use. The fact that finished welds can be made invisible, aids in giving the pleasing appearance that is such an important factor in attracting purchasers. From the manufacturer's point of view, welded construction is well adapted to the smooth production routine necessary for quality fabrication.

These points are well illustrated in the fabrication of welded aluminum chairs. Generally speaking, the parts that are assembled by welding are: the back and rear legs, the seat, the front legs, and the spreaders and rods. In the case of swivel chairs, the parts consist essentially of the back, the swivel base and the seat. These are assembled in jigs and welded by use of the oxy-acetylene flame. A welding rod suitable to the particular aluminum composition used is employed A good aluminum welding flux is necessary.

† General Publicity Department, The Linde Air Products Co.



A Finished Chair, Both Strong and Light, Has a Pleasing Appearance and Finish



Sketch of an Aluminum Welded Chair. The Letters Mark the Locations of Welds

Production Routine

The welding production routine is simple. The parts are received by the welding department, preformed and pressed to accurate and standard size. Uniformity of parts is, of course, essential if efficient jigging for welding is to be accomplished. Parts are assembled in the jig, and welded according to a carefully controlled procedure.

This process of welding assembly continues as the parts move along a conveyor system, so that when the frame comes off the end of the conveyor it has been completely welded into a solid unit. It has been thoroughly cleaned off and is ready for a subsequent heat-treating process, if this is necessary. Heat-treating may or may not be required, depending upon the type of material used.

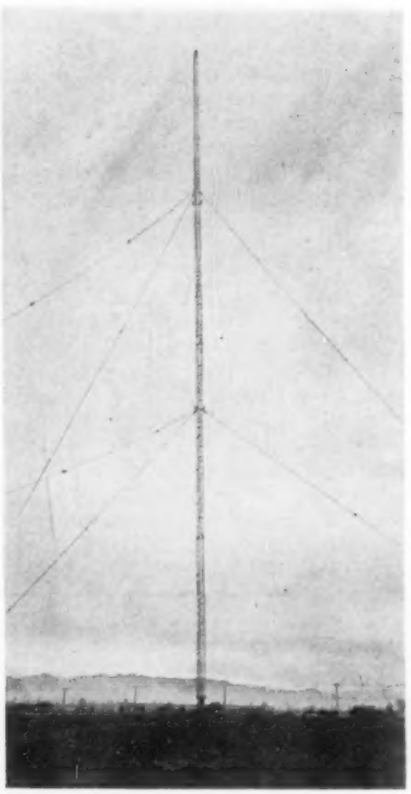
An important feature of welded fabrication is that the finished joints can be made invisible by grinding and polishing. Painting, enameling, spray finishing to resemble wood finishes, or sandblasting, are all possible on the smooth piece of metal which results when the welded joint has been ground to invisibility.

The accompanying illustrations show not only a finished chair of this type, but also a simple sketch indicating the locations of the welds.

Welded Broadcasting Tower for K.F.W.B.

By MERRITT L. SMITH†

IMPROVEMENTS to Station K.F.W.B. of the Warner Brothers Broadcasting Corporation, Hollywood, Calif., include a new raditor or broadcasting tower. Made by the International Derrick & Equipment Co. of Torrance, Calif., the tower is 450 feet high, triangular in section, and rests on a single large insulator. In constructing the tower, 20-foot sections were shop-fabricated by means of arc welding, using heavy coated electrodes. Erection consisted simply of bolting these sections together.



† Advertising Manager, Metal & Thermit Corp.

Address of Welcome at the Meeting of the National Board of Boiler and Pressure Vessel Inspectors' Convention in New York City, May 24, 1937

For the

American Welding Society

By D. S. JACOBUS†

I HAVE been asked to pinch hit for Mr. Crowe, who is listed on the program for extending the greetings of the AMERICAN WELDING SOCIETY. Both Mr. Crowe and I are past-presidents of the AMERICAN WELDING SOCIETY and it is for this reason that I will speak in his stead. It gives me great pleasure, therefore, to extend to you the greetings of the AMERICAN WELDING SOCIETY and to point out the usefulness of the work of this Society to your organization.

The AMERICAN WELDING SOCIETY was organized nearly 20 years ago to provide united and cooperative action in extending the knowledge of the art of welding and its field of industrial application. It is a comparatively small Society, its membership now numbering about 2000. In spite of its small membership it has been the acknowledged leader in its field. Its members have been most loyal and many have worked earnestly for the benefit of the Society. It has an enviable financial record in that through all of the years of the depression it did not run into debt. Its monthly Welding JOURNAL is acknowledged to be the leading authority on welding. It has 14 Technical Committees which, in turn, have a number of Subcommittees, these Committees dealing with subjects such as the Building Codes, Welding in Marine Construction, Nomenclature and Definitions, Correlation of Code Requirements for Qualification of Welding Operators, Welding Bridges, Welding Oil Storage Tanks, Standard Tests for Welds, Code for Pressure Piping, Committee on Filler Metal Specifications, Machinery Construction, Large Welded Pipe for Hydraulic Purposes.

One of the most active Technical Committees is the Conference Committee with the A.S.M.E. Boiler Code Committee, of which Mr. Obert is Chairman. As you know, the AMERICAN WELDING SOCIETY has cooperated with the Boiler Code Committee for a number of years in formulating rules for safe welding and it was through their joint efforts that the rules for welding the drums of steam boilers were incorporated in the Boiler Code in 1931. This cooperation has been most pleasing and helpful and has meant much to the welding industry as well as to boiler manufacturers and to your organization, which has to do with the inspection of welded boilers and pressure vessels.

One of the most useful activities of the Society has been to foster and encourage research in the welding field. This research was first done through the American Bureau of Welding and is now carried on by its Welding Research Committee, which is sponsored jointly by the AMERICAN WELDING SOCIETY and the American Institute of Electrical Engineers as an undertaking of the Engineering Foundation. It should not be inferred by this cooperation of the American Institute of Electrical Engineers that the Welding Research Committee is interested exclusively in electrical welding, as all fields of welding are covered. Engineering Foundation recognized the need of a comprehensive program of research in the welding field and appropriated $5000 a year for initiating a movement for the work of the Welding Research Committee, and a second appropriation of the same amount was made with the understanding that it would be supplemented by cash contributed from industry in a sufficient magnitude to enable the Committee to carry out its plans. Dr. Adams, who was Chairman of the original American Welding Bureau during all the years of its existence, is now Chairman of the Welding Research Committee and has collected upward of $20,000 from industry for the work of the present year. The work is conducted by three Special Committees, one on Industrial Research, of which Col. G. F. Jenks is Chairman; one on Literature, of which Mr. J. H. Critchett is Chairman, and one on Fundamental Welding Research, of which Mr. H. M. Hobart is Chairman.

Col. Jenks has divided the work of his Committee among 7 material Subcommittees and 4 functional Subcommittees, all of which are working actively on the subject.

Mr. Critchett's Committee has been active and the Digest of Literature on Welding which has been published has received the praise of numbers, who have found it a most useful help in their work. Several foreign countries are contemplating the translation and publication of these critical digests in their own language to make them available to their engineers.

Mr. Hobart has been Chairman of the Fundamental Welding Research Committee from the time that the AMERICAN WELDING SOCIETY was organized. There are now 50 projects being conducted under Mr. Hobart's guidance and many papers have been written on the results secured. That results secured in these investigations are useful is borne out by the special interest which is evidenced in the papers when they are presented at the meetings.

A Welding Handbook is being prepared by a Special Committee of the Society. It is proposed to include all technical information that a welding engineer, supervisor or inspector in general practice is likely to desire, presented in the most concise form possible by specialists whose experience will permit them to write authoritatively. Over 70 subjects are being covered by different authorities. In order that the information shall be as authentic as possible each chapter is reviewed by at least five experts in the line and afterward carefully edited. This work has been financed through advance subscriptions for the Handbook. It is hoped that the Handbook, which will have more than 600 pages of useful information, will be available before the end of the year.

As a result of all this work the Welding Society will soon be likely to offer additional valuable data concerning things the Boiler Code Committee needs to know, such as further information on stress-relieving and the nondestructive testing of welds. This will be of benefit to your own organization, as well as to the Boiler Code Committee, and shows the importance of the work of the AMERICAN WELDING SOCIETY in our particular field.

† Past-President

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BOOK

A bulletin on Arc Welding has recently been released by the Harnischfeger Corporation of Milwaukee. This brochure is of general interest in arc welding procedure.

WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

PRESIDENT'S MESSAGE

Cleveland, Ohio
May 20, 1937

Dear American Welding Society Folks:

I've been told by the editor that if I have anything to say to you in the next issue I'd better get it in quickly because he is going to get the JOURNAL in the mail by the 15th of the month in the future.

I can't remember if I wrote you a letter for the May issue. If I didn't, it wasn't because I had nothing to tell you. Things have been popping this last month. The May issue will tell you about our new Manager, Mr. Hays. I didn't furnish the copy for the JOURNAL, and as the May issue isn't out at this writing, I don't know what the story is. However, I have just returned from the NEMA Convention at Hot Springs, Va., where Mr. Hays and I outlined for them what the Society is doing. I wish you could have heard the reaction of those folks who make arc welding equipment and supplies. Hays' analysis of the Society, its aims and objectives displayed a very keen insight into our problems and how to solve them. Your Management Committee received many compliments on our choice of a Manager. While I'm on the subject of NEMA, I think you'll be interested to know the need stressed by these men whose business is to sell welders and electrodes. It was that they want the Society to push codes and procedures governing welding. They want order in the industry and they want to see the AMERICAN WELDING SOCIETY preeminent in the welding field as the one outstanding authority in this country.

On April 30th I spoke before the Welding Conference at the University of Wisconsin. They had a fine turnout and I have never received a more cordial reception than I received there. The matter of technical school welding education is vital and promising for future welding progress. It is a subject to which the Society should lend every aid.

A week later I repeated the same talk in Hamilton, Ontario, before some 250 men at a dinner meeting. Then last Friday your Executive Committee met in New York. Some important matters pertaining to codes were adopted, which will shortly be published in the JOURNAL. These had to do with symbols, Filler Metal specifications and correlation of code requirements for qualification of welding operators.

Our new Buffalo Chapter is over the top with more than enough members to qualify. Youngstown and Cincinnati will no doubt be in before June 1st. Mr. Hays is now on a swing through Indiana, Illinois and up as far as Minneapolis. He will then go to Texas. By the end of 1937, I am confident the twelve Chapters we had last fall will be doubled. In the last seven months approximately 700 new members have been enrolled. All of this, of course, means that a lot of people are doing constructive work for the Society, and these efforts backed up by Mr. Hays will, in my judgement, mean success.

Last week (this was just an experiment) Mr. Hays arranged a meeting at Erie, Pa., to which the welding interested people there were invited. I told them briefly about the AMERICAN WELDING SOCIETY, and Mr. Jennings of Westinghouse made a splendid talk which had that hall full of people sitting on the edge of their chairs for an hour and a half. Here's a tip to all our Sections—book Jennings for one of your meetings, if you can; this boy is good and he knows his welding.

Before the June issue is out our new St. Louis Section will be installed. Mr. Hays and I are to go there to help install this Section on Friday, June 4th. I've said it before, and I'll say it again, I'm betting on St. Louis. This city is welding minded, and they are going to be the one, two or three top notch local in the country.

I almost forgot, we have another new Section—Honolulu. Whitey Murath is there now, and what Whitey can't tell them about the Society, won't be worth much when he gets one of those lei around his neck and an "old fashion" in each hand.

The committees in charge of the annual meeting at Atlantic City have been hard at work. The program of technical sessions is about complete. This committee has so much good material that their hardest job was to decide what had to be left out. The arrangements for the hotel, meeting rooms and entertainment are set; the space for the show is well taken, and this year's meeting will be outstanding. Start telling the boss about it and the necessity for your attending. If you can't come back with enough new knowledge and inspiration to make the trip a fine investment for your company, there is something wrong with you.

Now that summer is almost here and the active local programs finished, don't forget your interest in the Society; don't forget about that new member you were to get last winter and didn't. There isn't a reason in the world why the Society shouldn't have 1000 more members in December than it had last October—no reason except that you haven't done your job. You won't let us down, will you?

Sincerely,
A. E. Gibson,
President

Lang Nominated!

The dynamic Chairman of our Bridge Committee, Philip George Lang, Jr., has been nominated for the Presidency of the AMERICAN WELDING SOCIETY.

In less than two years after its appointment, the A.W.S. Bridge Committee under the direction of Mr. Lang brought forth a 66 page specification which was promptly adopted by the Board of Directors of the Society, approved by the Association of State Highway Officials, the Bureau of Public Roads and endorsed by the appropriate committee of the A.E.R.A.

When the Society wanted to organize a Section in Maryland, Philip Lang was again asked to engineer the job and in his quiet, unassuming way, promised to help and there shortly came in existence the Maryland Section which now has sixty members.

Some of Mr. Lang's friends look upon him as an outstanding Bridge Engineer, others as a Railroad Executive of high order, and to still others he appears as an author (he has written more than sixty engineering articles).

Youngstown Section Formed

The following officers were elected by the newly organized Youngstown Section on May 20, 1937

Chairman—Mr. Charles Watson, President, Youngstown Welding & Engr. Co., Youngstown, Ohio.
Vice-Chairman—Mr. Fred P. McBerty, President & General Manager, Federal Machine & Welding Co., Warren, Ohio.
Secretary—Mr. C. A. Wills, Wm. B. Pollock Co., Youngstown, Ohio.
Treasurer—Mr. John Moriarity, The Linde Air Products Co., Youngstown, Ohio.
Section Director, A. W. S.—Mr. G. A. Reinhardt, Youngstown Sheet & Tube Co., Youngstown, Ohio.
Members of Executive Committee:
Mr. Tross, Youngstown, Ohio
Mr. Emery, Salem, Ohio
Mr. Tam, Greenville, Pa.
Mr. C. Wheeler, New Castle, Pa.
Mr. C. E. McGill, Greenville, Pa.
Mr. Watkins, Columbiana, Ohio
Mr. G. A. Hughes, Youngstown, Ohio
Mr. Warrander, Sharon, Pa.
Mr. Fred Huggins, Warren, Ohio

Mr. Robert Kinkead, Consulting Engineer, delivered an address on the benefits of affiliation with the AMERICAN WELDING SOCIETY.

A Dangerous Welding Problem

A note in *Electric Welding* describes the method by which an unusual and somewhat dangerous welding problem was overcome. One of a group of steel tanks used for the storage of methanyl and other inflammable solvents in a chemical works developed a leak in a 2-in. screw plug in the center of the bottom. These tanks are 10 ft. high and 10 ft. in diameter, half buried in sand as a safety measure. Several hundred gallons of the solvent had leaked into the ground before the leak was discovered. It was decided to weld a steel cap around the plug hole inside the bottom. The cap was 14 in. in diameter by 3 in. deep. To prevent inflammable vapor penetrating from the ground and to make the atmosphere in the tank inert, solid carbon dioxide was packed round the plug seat, 3 in. thick by 12 in. diameter. The cap was placed over this and successfully arc welded to the bottom without any trouble.

Strength of Welded Joints in Aircraft Parts

Welding plays an important part in the construction of the modern airplane because it is an efficient method of joining steel sheet and tubular members. Accurate information is necessary on the strength of welds in chromium-molybdenum steel (the alloy generally used) in order that aircraft may be safely and efficiently designed. Continuing as investigation of which one report has already been published (NACA Technical Report 348) further tests have been made on typical welded joints in chromium-molybdenum steel tubing and sheet. The results have just been made available as NACA Technical Report 584, obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. at 15 cents a copy.

Tests were made on three kinds of oxyacetylene welds consisting of: (1) welds made by the usual process in which low-carbon steel welding rod and a neutral flame were used; (2) similar welds made with chromium-molybdenum steel welding rod; and (3) the recently developed "carburizing flux" process in which a special technique with an excess acetylene flame was used. In welding joints in tubing having a very thin wall ($1^1/_2$ in. outside diameter by 0.020-in. wall) only the carburizing flux process was found to produce joints which were free from cracks. These were detected by means of the "magnetic dust" method of inspection. Butt joints in heavier chromium-molybdenum tubing and sheet made by the three kinds of welds had about equal strengths in the "as-welded" condition. When heat-treated the joints made by the carburizing flux process and those welded with chromium-molybdenum rod were stronger than joints in which low-carbon welding rod was used.

The strength of tubular joints loaded under tensile, compressive and bending stresses have been determined, both "as-welded" and in the heat-treated condition. In some kinds of joints it was found that gusset plates inserted in slots in the tubing materially increased the strength.

Members Honored

Announcement of those who will receive the 1937 Medal Awards of The Franklin Institute of the State of Pennsylvania, for scientific ingenuity and skill, for invention and discovery, was made by Henry Butler Allen, Secretary. The awards were formally presented in the Hall of the Institute at its Medal Day exercises, Wednesday afternoon, May 19th.

To MR. HERBERT L. WHITTEMORE, Chief, Engineering Mechanics Section, National Bureau of Standards, Washington, D.C., "In consideration of his part in the invention and development of the Proving Ring for the direct checking of calibrations of testing machines."

The *Louis Edward Levy Medal*, founded in 1923 by the family of the late Louis Edward Levy, Philadelphia, a member of the Committee on Science and the Arts of The Franklin Institute at the time of his death, who had previously served the Institute as a member of the Board of Managers for twelve years and a Vice-President for three years, is awarded "to the author of a paper of especial merit, published in the Journal of the Franklin Institute, preference being given to one describing the author's experimental and theoretical researches in a subject of fundamental importance." It will be given to MR. INGE LYSE, Research Associate—Prof. of Engineering Materials, Lehigh University, Bethlehem, Pa., "For his series of Papers on 'A Study of the Quality, the Design and the Economy of Concrete,' published in the April, May, June and July issues of the Journal of the Institute for 1936."

World's Largest Precision Instrument

200-Inch Telescope
California Institute of Technology
Mt. Palomar, Calif.

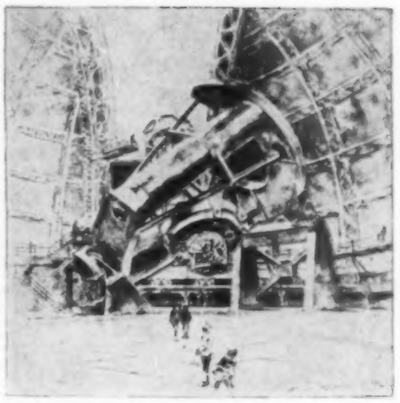
(*A group of thirty Editors, including W. Spraragen, Editor,* THE WELDING JOURNAL *were invited by the Westinghouse Co. to examine the frame work of this telescope.*)

($6,000,000 provided by Rockefeller Foundation)

200-Inch telescope is largest in world—twice the size of the next largest 100-inch telescope at Mt. Wilson—will weigh eight times that of Mt. Wilson equipment.

Location on Mt. Palomar selected because of ideal weather conditions and isolation—no sky glare from lights of surrounding cities—comparatively small range of temperatures—mountain is 6000 feet high and is about 90 miles distance from Los Angeles and 60 miles from San Diego—about 50 miles inland from coast.

New road, about 20 miles in length, being constructed up mountain from main highway. Reasons for wanting 200-inch telescope—permit astronomers to go twice as far into space as heretofore possible—



widen volume that may be observed eight times—also permit more accurate observations as astronomers will be enabled to see better everything they now observe due to fact that 200-inch telescope collects four times as much light as best telescope now in existence.

Observers may see objects 1,000,000,000 light years distant, whereas they now can see but 500,000,000 light years away.

Weight of telescope, including mounting is approximately 1,000,000 pounds—height, overall, when tube is pointed straight up is 75 feet—(all material will be hauled up mountain side, in trucks, for erection purposes). Westinghouse will ship tube complete, this probably will be the largest single item ever placed on board a ship.

Yoke to which tube is attached floats on oil at pressure of 250 pounds per square inch—remarkable feature is ease and smoothness with which yoke may be moved—calculated that it requires by $^1/_{165,000}$ horsepower to move yoke, which moves at the rate of one revolution per day—practical operation requires installation of one-half horsepower electric motor.

First time that telescope mounting has ever floated on oil—others have used mercury bearings—estimated that if conventional type of roller bearings were used, friction would be 600 times greater than with oil float.

Motor Ships

Two new canal motor ships, the largest of their kind ever built for service between the Great Lakes and the Atlantic Coast (via New York State Barge Canal), will be added to the Ford Motor Company's fleet in June, it was announced today at the company's home offices.

The vessels, now under construction at River Rouge are to ply between the Ford Rouge Plant at Dearborn, Mich., and the company's plants at Edgewater, N. J., Chester, Pa. and Norfolk, Va. The first is scheduled to go into service about June 1, the second about June 15.

They will be the first freight carriers on the Great Lakes having no riveting in hull and deck construction. Welding is being used throughout. They will

each be driven by two 600-horsepower Diesel engines, and will carry crews of 18-men each. They are stern driven, with a three-to-one gear reduction from engine to propellor.

The craft will be equipped with the latest devices and apparatus for navigation control. They will be 300 feet long, and have a 43 foot beam and 20 foot depth. They are being built as large as possible in keeping with the length and width of locks in the New York State canal system through which they will go.

In many respects the new marine carriers will be much like the Chester and Edgewater, two sister ships of the Ford fleet used for canal trade, which were the largest geared turbine propelled steamers in the world when constructed for Ford in 1931. They will have a disappearing superstructure, to permit passage beneath Erie Canal bridges. The pilot house will rest on a hydraulic lift, to be lowered or raised as desired. Funnels will be tilted, and masts will be raised and dropped within pipes so that the ships will be able to pass beneath bridges only 15 feet above water level.

The new boats will have a freight capacity of 2200 tons, slightly exceeding that of the Chester and Edgewater. This will enable them each to carry nearly 2000 V-8 engines with all axles and heavier parts necessary for assembling 2000 Ford cars or trucks. The motor ships will have a speed of $11^1/_2$ knots per hour.

The two all-welded, Diesel-powered vessels will be newcomers to a Ford fleet which already includes well over a score of units. Freighters and barges transport coal, sand, lumber and ore from Great Lakes ports to the Rouge Plant, and carry automobile parts to various branches. Other steamships operate between branches on the Atlantic and Pacific coasts through the Panama Canal, others transport knocked-down cars to South American branches, and still others operate between the Dearborn plant and the Ford rubber plantations in Brazil. Rail and motor-truck transportation are complements, of course, of the Ford Company's extensive use of water routes for shipping purposes.

Battelle Research Associates

Four appointments as Research Associate will be available at Battelle Memorial Institute, Columbus, Ohio, for the year 1937–38. Appointments are for September to August inclusive. These appointments are open to graduates of any accredited university or college. Preference will be given to men who have completed one or more years of graduate study in chemistry, physics, metallurgy, fuel technology or ceramics; or who have demonstrated marked aptitude for scientific research in their industrial experience.

The Research Associates will be members of a new division of the Institute which will supplement the regular technical staff. The purpose of the Research Associate Division is to extend the work of the Institute in fundamental science and at the same time to develop highly trained research men for industry.

Appointments as Research Associate will be for one year's duration, including vacation, and may be extended for a second year. The salary will be from $1200 to $1800 a year, depending upon the training and experience of the individual. Research Associates will be expected to devote their entire time to a research project approved by the Director and supervised by members of the Institute staff. Research projects will be of a fundamental or general character looking toward the publication of information that will be useful to science and industry.

Battelle Memorial Institute was established under the will of Gordon Battelle to contribute to industrial progress through scientific research. The activities of the Institute are carried on under nine main divisions: applied chemistry, industrial physics, process metallurgy, physical metallurgy, ceramics, refractories, fuel technology, ore dressing and coal washing. Each division is equipped and staffed to carry on research under the direction of a specialist who is qualified by training and experience to direct original research in his field.

Application forms and further information may be secured by writing the Director, Battelle Memorial Institute, Columbus, Ohio.

Gilbert E. Doan Advanced

Members of the AMERICAN WELDING SOCIETY will be particularly glad to learn that Dr. Gilbert E. Doan, Associate Professor of Metallurgy, Lehigh University, has been advanced by the Board of Trustees to the position of Professor of Metallurgy.

SECTION ACTIVITIES

CHICAGO

"New Developments in Welding" was the subject of the meeting held on May 21st at the Mission Hall, Armour Institute of Tech. Mr. T. C. Fockler, Westinghouse Elec. & Mfg. Company, presented an address on "Welded Machine Designs" and Mr. A. N. Kugler of the Air Reduction Sales Co., spoke on "Multi-Layer Oxyacetylene Pipe Welding." Mr. H. C. Boardman of the Chicago Bridge & Iron Co., read the English translation of a German paper on Krupp's new welding method, translation of which was furnished by the Fundamental Research Committee. After these most interesting addresses discussion followed.

DETROIT

A joint meeting with the American Society of Mechanical Engineers was held at the Hotel Statler on May 19th. Mr. Everett Chapman, President, Lukenweld, Inc., addressed the meeting on "Welded Steel in High-Speed Railway Service" and Mr. C. L. Eksergian, Chief Engineer, Budd Wheel Company, presented an address on "Hydromatic Welding of Frames." This was the last meeting of the season for the Detroit Section.

KANSAS CITY

The third regular monthly meeting of the Kansas City Section was held on May 17th. Those present thoroughly enjoyed the lecture by Mr. L. J. Larson, Research Engineer in charge of Welding Research of the A. O. Smith Corporation, whose topic covered an explanation of all welding processes known and used at the present time.

LOS ANGELES

The regular meeting was held May 20th at the Central Manufacturing District Club Rooms with 115 members and guests present. Dinner was served at 6:30 P.M., after which the meeting was called to order by Chairman Wayne Howard.

The topic for the evening was "Building the World's Largest Telescope."

The first speaker, Dr. John A. Anderson of the California Institute of Technology, discussed, in the language of the layman, the optical theory of this huge instrument. He also described the many problems which were encountered in casting, grinding and polishing the 200-inch mirror.

The second speaker was Mr. Mark Serrurier, Structural Engineer and designer of the supporting structure. Mr. Serrurier gave a word picture of the research necessary to develop a suitable structural steel mounting for the world's largest telescope.

The next meeting will be held June 10th, at which time Mr. George A. Maurath of Maurath, Inc. will talk on "Welding of Stainless Alloys."

MILWAUKEE

A technical meeting was held by the Milwaukee Section on May 27th, at the City Club of Milwaukee. "Recent Developments in Machine Cutting with the Oxyacetylene Flame" was presented by Mr. Gus Johnson, Welding Engineer, Air Reduction Sales Company; and "Hard Facing" was presented with illustrations by moving pictures by Mr. E. F. Smith, District Manager, Haynes Stellite Co.

SAN FRANCISCO

The Annual Meeting of the San Francisco Section was held on May 21st at the Athens Athletic Club. The major portion of the evening was devoted entirely to a good fellowship get together. Prizes were awarded for the funniest personal experience in the welding business, the funniest or snappiest story of the evening and the biggest boner ever pulled in the welding business.

WESTERN NEW YORK

A very successful meeting of the Western New York Section was held on May 7th at the Hotel Statler, at which there were present about 125 persons. Mr. Leon C. Bibber, Welding Engineer of the Carnegie-Illinois Steel Corp., presented as his subject "Welding Standards," including the AMERICAN WELDING SOCIETY'S new symbols; also Mr. D. E. Roberts, Engineer of The Linde Air Products Co., gave a very interesting talk accompanied by motion pictures of Automatic Flame Cutting. There will be no further meetings of this Section until the Fall, but a meeting of the members will be held during the month of June for the election of officers for the coming year.

Welding Handbook

The Editorial Committee presents below the latest revised list of chapters in the handbook. More than 60% of the chapters are already in hand and have been submitted to various authorities for critical review.

The Committee would welcome suggestions for additional chapters to reach the Committee not later than July 1st. It will not be possible to arrange for the preparation of additional chapters after that date.

AMERICAN WELDING SOCIETY

List of Authors

WELDING HANDBOOK

PREFACE

Economics of Welding . . . . . J. F. Lincoln

PROCESSES

Chart of Processes with Explanatory Text

Technical Fundamentals:
- Arc Welding—J. W. Owens, Fairbanks-Morse Company
- Gas Welding—J. H. Critchett, Union Carbide & Carbon Res. Labs.
- Thermit Welding—J. B. Tinnon, Metal & Thermit Corporation
- Resistance Welding:
  - General—R. L. Briggs, Thomson Gibb Electric Welding Company
  - Spot—H. A. Woofter, Federal Machine & Welder Company
  - Wheels, Points and Clamps—J. A. Weiger, P. R. Mallory & Co.
  - Controls—C. Stansbury, Cutler-Hammer Co. (In cooperation with General Electric Co. & Westinghouse E. & M. Co.)
  - Tensile and Shear Strengths—G. A. Hughes, Truscon Steel Company
- Metallurgy of Welds—J. C. Hodge, Babcock & Wilcox Company
- Alternating Current Arc Welding—C. J. Holslag, Electric Arc Cutting & Welding Company

Collateral Processes:
- Oxyacetylene Cutting—J. J. Crowe, Air Reduction Sales Company
- With Other Fuel Gases—E. M. Eveleth, Bastian Blessing Co.
- Arc Cutting—C. J. Holslag, Electric Arc Cutting & Welding Co.
- Stress Relieving—S. C. Hollister, Cornell University
- Soldering (Soft and Silver)—R. H. Leach, Handy & Harman and Geo. O. Hiers, National Lead Co.
- Surfacing (Hard and Tough)—(J. R. Spence, Stoody Co.
- Sprayed Metal Coatings—E. V. David, Air Reduction Sales Co.

Special Processes:
- Atomic Hydrogen—J. T. Catlett, General Electric Company
- Shielded Arc—F. J. Aschenbrenner, Wilson Welder and Metals Co.

Automatic Processes:
- Metal Arc Welding—C. H. Jennings Westinghouse Elec. & Mfg. Co.
- Gas Welding—J. L. Anderson, Air Reduction Sales Co.
- Carbon Arc Welding—A. F. Davis, Lincoln Electric Co.
- Resistance Welding—R. T. Gillette, General Electric Co.

Accessories:
- Jigs and Fixtures—
  - For Resistance Welding—H. C. Cogan, National Electric Welding Machine Co.
  - For Arc and Gas Welding—Owen C. Jones, The Linde Air Products Co., A. N. Kugler, Air Reduction Sales Company, and a representative of the Westinghouse Elec. & Mfg. Co.
- Protective Appliances—Thomas A. Willson, Vice-Pres., Willson Products, Inc.

MATERIALS AND TESTING

Base Metal—Ferrous:
- Carbon Steel—F. N. Speller, National Tube Company & N. L. Mochel, Westinghouse Elec. & Mfg. Co.
- Cast Iron with Bronze—A. R. Lyttle, Union Carbide & Carbon Res. Labs.
- High Manganese Steels—John Howe Hall, Taylor-Wharton Iron & Steel Co.
- Alloy Steels:
  - Chromium Irons and Steels—E. C. Chapman and A. J. Moses, Hodges-Walsh, Weidner Company
  - Austenitic Chrome Nickel Steels—G. S. Mikhalapov, Heintz Manufacturing Co.
  - Low Alloy Steels—A. E. Gibson, Wellman Engineering Co. and J. C. Hodge, Babcock & Wilcox Co.

Base Metal—Non Ferrous:
- Copper and Its Alloys—I. T. Hook, American Brass Company
- Aluminum and Its Alloys—G. O. Hoglund, Aluminum Company of America
- Nickel and Its Alloys—J. G. Schoener and F. G. Flocke, International Nickel Company

Filler Metal:
- Standard Specifications—C. A. McCune, Magnaflux Corporation
- Covered Electrodes—J. H. Deppeler, Metal & Thermit Corporation

Tentative Rules for the Qualification of Welding Processes and Testing of Welding Operators

Testing:
- Non-Destructive Tests—Magnetic and Sonic—A. V. DeForest, Massachusetts Institute of Technology
- —Radiography—H. H. Lester, Watertown Arsenal
- Fatigue Tests—H. F. Moore, University of Illinois
- Inspection of Pressure Vessels—E. R. Fish, Hartford Steam Boiler Insp. & Ins. Co.
- Welding Symbols—L. C. Bibber, Carnegie-Illinois Steel Corp.
- Testing of Electrodes, of Welding Technique or Procedure, of Welders and Welds in Naval Work—Bela Ronay, U. S. Naval Engineering Experiment Station

Welding Codes—
- Safe Practices in Welding

APPLICATIONS

Marine Construction:
- Ships—G. H. Moore, Jr., Newport News Shipbuilding & Dry Dock Co.
- Barges—C. W. Bryan, Jr., Federal Shipbuilding & Dry Dock Co.
- Insurance of Welded Ships—David Arnott, American Bureau of Shipping

Pressure Vessels:
- Gas Welding—G. W. Plinke, Henry Vogt Machine Company
- Progressive Welding—John Wood Manufacturing Co.
- Petroleum Vessels—T. McLean Jasper, A. O. Smith Corporation
- Boilers—M. Christenson, Babcock & Wilcox Company
- Thin Wall Vessels—R. E. Cecil, W. B. Scaife & Sons Company
- Evaluating Existing Vessels—W. Samans, Atlantic Refining Company
- Vessels for Low Temperatures—R. K. Hopkins, The M. W. Kellogg Company

Storage Tanks:
- Field Welding—H. C. Boardman, Chicago Bridge & Iron Works and W. Samans, Atlantic Refining Company

Piping and Fittings:
- Gas Welding—A. W. Moulder, Grinnell Company
- Arc Welding—D. H. Corey, Detroit Edison Company
- Resistance Welding (Longitudinal Joints)—W. M. Neckerman, Republic Steel Company

Pipe Lines of Large Diameter:
- Arc Welding—H. C. Price, H. C. Price & Company
- Gas Welding—F. C. Hutchison, Union Carbide Company

Structural Steelwork:
- Buildings—Gilbert D. Fish, Consulting Engineer
- Bridges—P. G. Lang, Jr., Baltimore & Ohio Railroad Co.
- Welding Fabrication—Albert S. Low, The Austin Company

Street Railway Track—E. M. T. Ryder, Third Avenue Railway System

Machinery:
- General—Everett Chapman, Lukenweld, Inc.
- Locomotive Construction—J. Partington, American Locomotive Company
- Steel Mill Equipment—H. G. Marsh, Carnegie Illinois Steel Corp.

Automotive Products—C. A. Bowlus, General Motors Corporation, Export Division

Aircraft—J. B. Johnson, Material Branch, Air Corps, War Department

Railroad Rolling Stock:
- Standard—J. W. Sheffer, American Car & Foundry Company
- Light Weight—E. J. W. Ragsdale, E. G. Budd Manufacturing Company

Under Water Gas Cutting—C. Kandel, Craftsweld Equipment Company

Repair and Maintenance—A. F. Keogh, Sound Welding Company

Maintenance of Way Welding:
- Arc and Gas—H. E. Gannett, Chicago, Burlington & Quincy R. R.

Rail Joint Welding:
- Resistance and Thermit—H. S. Clarke, Delaware & Hudson R. R.
- Oxyacetylene—

Railroad Repair—J. E. Martin, Cleveland, Cincinnati, Chicago & St. Louis Ry.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-239 Young man, age 35, graduate engineer, who specialized in welding, research activities in the structural field and welding in general, also gas and electric welder, desires position as welding engineer or draftsman.

A.S.T.M. Annual Meeting

The Fortieth Annual Meeting of the American Society for Testing Materials to be held at the Waldorf-Astoria, New York City, June 28th to July 2nd, will include as features an address by the President, A. C. Fieldner, Chief, Technologic Branch, U. S. Bureau of Mines, on the subject "Fuels of Today and Tomorrow" and also the Twelfth Edgar Marburg Lecture on "Plastics: Some Applications of the Different Classes, Methods of Testing" to be delivered by Dr. T. Smith Taylor, Professor of Physics, Washington & Jefferson College. Throughout the week of the meeting there will be in progress the Fourth A.S.T.M. Exhibit of Testing Apparatus and Related Equipment in which leading organizations in the instruments and laboratory supply and related fields will display new developments and which will also include special displays sponsored by various research laboratories.

Bridge Specifications Endorsed

Subcommittee 2—Fusion Welding—of American Railway Engineering Association Committee XV, at its meeting in Pittsburgh, May 6th and 7th, recorded itself as follows:

"Reported that its members expected to recommend to the Committee the endorsement for use of the AMERICAN WELDING SOCIETY Specifications for Design, Construction, Alteration and Repair of Highway and Railway Bridges by Fusion Welding, and that this specification will be considered in detail at the July meeting, at which meeting it is strongly urged that the five members of Committee XV who are members of the AMERICAN WELDING SOCIETY be present.

"The Subcommittee called the attention of Committee members to the excellent article in the January issue of the AMERICAN WELDING SOCIETY JOURNAL, and urged all to read it before the July meeting."

Notvest Appointed Sales Representative

The Champion Rivet Company, Cleveland, Ohio, has appointed Mr. R. Notvest, as their exclusive Sales Representative on Welding Electrodes for the Southern Illinois and St. Louis Territories. He will retain his present headquarters at 457 So. Arlington, Indianapolis, Ind.

Rail Experts Ride Over "Velvet" Track

ALBANY, May 27 (A.P.).—Nearly sixteen miles of "velvet" tract, the result of the Delaware & Hudson Company's pioneer use of the "continuous weld," was tested today by an inspecting party representing several railroads of this country and Canada.

The group started their tour here and proceeded to Schenectady, Saratoga and Port Henry.

The "velvet" description comes from locomotive pilots, H. S. Clarke, D. & H. engineer in charge of maintenance of way, explained, because of the comfort the process has added to the train tide.

The Delaware & Hudson, Mr. Clarke said, was the first railroad in the United States to eliminate the rail-joint over long stretches by welding, and expects, he added, to save ultimately at least 50 per cent of its rail-maintenance costs as a result.

Since 1933 the company has put down 84,086 feet of welded rail, with the longest single piece 6950 feet, near Schenectady. The rail at that point is broken because of a signal installation and then continues again unbroken for another long distance.

Mr. Clarke quoted L. A. Downs, president of the Illinois Central system, as saying that "fully 50 per cent of the expense of track maintenance is incurred at the rail joints."

"Seventy per cent of rail renewals," Mr. Clarke added, "are caused by battered ends of the now standard thirty-nine-foot rail. But economy is only one benefit of the continuous rail. I believe that it will greatly increase safety for the lighter, high-speed modern trains because removal of rail joints decreases the sway of cars."

With nearly sixteen miles of the new trackage already down, the Delaware & Hudson hopes to increase that figure to 39.96 miles by the end of this Summer. Eventually, Mr. Clarke said, it is planned to use "continuous" rail over the entire 1272 miles of the road's main-line trackage.

TENTATIVE PROGRAM EIGHTEENTH ANNUAL MEETING AND WELDING EXPOSITION OF THE AMERICAN WELDING SOCIETY

OCTOBER 18–22, 1937

ATLANTIC CITY, N. J.

Headquarters for Technical Sessions and Committee Meetings—Hotel Traymore

Exposition—Convention Hall

Monday, October 18th

Morning

9:30 A.M. Business Session.

President A. E. Gibson, *presiding*

Report on Society activities by President Gibson.
Report on Welding Research Activities by C. A. Adams.
Tellers' Report on Election of Officers.
Award of Samuel Wylie Miller Memorial Medal.
Award of Lincoln Medal.
Review of Committee and Section Activities by Chairmen.
Discussion.

Afternoon

2:00 P.M. Technical Session.

G. F. Jenks, *Chairman*, Col. Ord. Dept., U. S. Army.
E. Vom Steeg, *Vice-Chairman*, General Electric Company.

INDUSTRIAL RESEARCH

Weldability of Low Alloy Steels, by W. L. Warner, Watertown Arsenal.
Recent Progress in Welding of Copper Alloys, by D. K. Crampton and J. J. Vreeland, Chase Brass & Copper Company.
Survey of Low-Alloy Steels as to Weldability, by J. H. Critchett, Union Carbide & Carbon Res. Laboratories.
Physical Properties and Corrosion Resistance of Nickel–Iron Alloys Formed in the Welding of

Nickel-Clad Steel, by J. H. Deppeler, W. G. Thiesinger and F. G. Flocke.
The Problem of Correlation of Radiographs and Mechanical Tests of Welds, by J. T. Norton, Massachusetts Institute of Technology.

Evening

6:30 P.M. Board of Directors' Meeting

Dinner followed by meeting.
Review of Society activities, appointment of committees and officers.
New Business.

Tuesday, October 19th

Morning

9:30 A.M. Technical Session.

Charles I. MacGuffie, *Chairman;* General Electric Company.
Otto H. Henry, *Vice-Chairman;* Polytechnic Institute of Brooklyn.

FUNDAMENTAL RESEARCH IN WELDING

A Study of Stress Relief in Metals by an X-Ray Method, by J. T. Norton, Massachusetts Institute of Technology.
Welding Strength as Affected by Internal Stresses, by J. P. Den Hartog, Harvard University.
Proximity Effect in Welding Problems, by E. Bennett, University of Wisconsin.
The Heat Effect in Welding—by W. H. Bruckner, U. S. Naval Research Laboratory.

Afternoon

Two Simultaneous Technical Sessions

FUNDAMENTAL RESEARCH IN WELDING

2:00 P.M. Technical Session

T. M. Jackson, *Chairman*, Sun Shipbuilding & Dry Dock Company.
J. H. Zimmerman, *Vice-Chairman*, The Linde Air Products Company.
Stresses in Fillet Welds When Subjected to Bending Action, by Cyril D. Jensen, Lehigh University.
Welding of Copper, by A. P. Young, Michigan College of Mining & Technology.
Static and Impact Tensile Properties of Stainless Steel Welds at Ordinary and Low Temperatures, by O. H. Henry, Polytechnic Institute of Brooklyn.
Effect of Welded Clip Angles on Beam-Column Connections, by Inge Lyse, Lehigh University.
High Speed Motion Pictures of Flame Cutting, by H. R. Bullock, Massachusetts Institute of Technology.

JOINT SESSION WITH AMERICAN SOCIETY OF MECHANICAL ENGINEERS

2:00 P.M. Technical Session

Resistance Welding Fabrication, by J. M. Cooper, General Electric Company.
Fusion Welded Fabrication, by H. N. Blackmon, Westinghouse Electric & Mfg. Co.

Evening

7:30 P.M. Conference and Meeting of Fundamental Research Committee.

H. M. Hobart, *Chairman*, General Electric Company.
This conference is scheduled for university research workers in the fundamentals of welding.

Wednesday, October 20th

Morning

9:30 A.M. Technical Session

P. G. Lang, Jr., *Chairman*, The Baltimore and Ohio R. R. Company.
A. F. Davis, *Vice-Chairman*, The Lincoln Electric Company.

RAILROAD SESSION

Building Up Locomotive Drive Box, by I. T. Bennett, Revere Copper & Brass, Inc.
Machine Gas Cutting in Railroad Work, by H. Bass, New York Central Railroad.
Welding of Railroad Rolling Stock, by V. R. Willoughby, American Car and Foundry Co.

Afternoon

2:00 P.M. Technical Session

H. C. Boardman, *Chairman*, Chicago Bridge & Iron Works.
E. V. David, *Vice-Chairman*, Air Reduction Sales Company.

FABRICATION

Carbon Arc Welding in Automotive Work, by William Richards, Chevrolet Motor Co.
Automatic Resistance Welding, by Harry Landstrom, Nash-Kelvinator Corp.
Arc Welding of Steel Mill Machinery, by E. E. Tross, Gen. Supt., United Engineering & Foundry Company.
Welding—An Aid in Dam Construction.

Thursday, October 21st

Morning

9:30 A.M. Technical Session.

Everett Chapman, *Chairman*, Lukenweld, Inc.
Milton Male, *Vice-Chairman*, U. S. Steel Corporation.

SYMPOSIUM ON ALLOY STEELS

Low Alloy Steels—G. S. Mikhalapov, Heintz Manufacturing Company.
High Alloy Steels—T. R. Lichtenwalter, and V. W. Whitmer, Republic Steel Corp.; W. B. Miller, Union Carbide & Carbon Res. Labs.; J. C. Holmberg, Struthers-Wells-Titusville Corp.; R. Vincent, President, Alloy Fabricators.

Afternoon

2:00 P.M. Technical Session.

W. M. Mitchell, *Chairman*, Carnegie-Illinois Steel Corp.
J. J. Crowe, *Vice-Chairman*, Air Reduction Sales Company.

SHIPBUILDING

Welding in Building Tanker Vessels, by T. M. Jackson, Sun Shipbuilding & Dry Dock Co.
Assembly Plant for the Welding of Barges, by Geo. F. Wolfe, Dravo Corporation.
Welding of Naval Vessels.
Ship Welding, by J. Lyell Wilson, American Bureau of Shipping.

Friday, October 22nd

Morning and Afternoon

COMMITTEE MEETINGS

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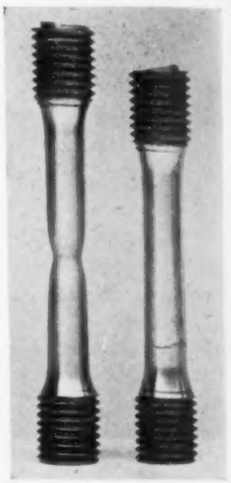
FOOTE

WELDING ROD COATING MATERIALS AND FLUXES



A Comparison of the ductility of Weld Metal Deposited with Covered Electrodes (left) and Bare Electrodes (right).

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